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HISTOLOGICAL AND CYTOLOGICAL STUDIES ON THE FIJI DISEASE OF SUGAR CANE.

FURTHER STUDIES ON THE INTRA-CELLULAR BODIES ASSOCIATED WITH CERTAIN MOSAIC DISEASES.

STUDIES ON THE MOSAIC OF SUGAR CANE.

BY

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HONOLULU, HAWAII

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LETTER OF TRANSMITTAL.

To the Experiment Station Committee
of the Hawaiian Sugar Planters' Association,
Honolulu, T. H.

Gentlemen:

I transmit herewith for publication as a bulletin of the Botanical Series, three papers on sugar cane diseases by Dr. L. O. Kunkel:

Histological and Cytological Studies on the Fiji Disease of Sugar Cane,

Further Studies on the Intracellular Bodies Associated with Certain Mosaic Diseases,

Studies on the Mosaic of Sugar Cane.

These papers are based upon investigations conducted by Dr. Kunkel while he was Associate Pathologist of this Experiment Station, March, 1920, to June, 1923.

Yours very truly,

H. P. Agee,
Director.

Honolulu, T. H.,
April 2, 1924.

HISTOLOGICAL AND CYTOLOGICAL STUDIES ON THE FIJI DISEASE OF SUGAR CANE

By L. O. Kunkel.

In 1910 Lyon[9] described a new cane disease that was then epidemic in Fiji. From this and later work we learn that the disease may be recognized by the following symptoms: stunting of the plant, shortening and crumpling of the youngest leaves, occurrence of burned or scalded areas on the upper parts of crumpled leaves, death of the stem tip and upper leaves, abnormal production of lalas, abnormally deep green color of leaves[13] and the presence of galls on the under side of leaves and in the tissues of the stalk. Lyon states that "The one critical symptom by which Fiji disease may be recognized is the occurrence of elongated swellings or galls on the under surface of the leaves."[11] All who have studied the disease seem agreed that the most important symptom is the presence of galls, and there is good reason to believe that these overgrowths are the seat of the trouble. The other symptoms are probably secondary.

Since 1910, Fiji disease, which is the name under which this disorder has come to be known, has been reported from New Guinea[10], Australia [4,10] and the Philippine Islands [5,13]. It was found on native canes in New Guinea, where it is believed to be endemic. Apparently it is not widespread either in Australia or the Philippine Islands. According to Muir[12], Lyon[9], Reinking[13], and others who have observed diseased fields, it is a serious hindrance to sugar cane culture. Since the disease has not yet reached most of the cane growing countries of the world, it is important that every effort be made to prevent any further spread.

Fiji disease is one of the obscure plant maladies which are by no means well understood. Lyon[9,11] observed and described intracellular bodies in the gall tissues. He believes that these bodies represent a parasitic organism. However, the bodies do not resemble any of the intracellular parasites associated with other plant diseases. It is not known whether they represent a new type of parasite or should be looked on as inert bodies associated with the diseased condition. It is probable, however, that a better knowledge of the disease and of the means by which it spreads will lead to an understanding of the nature of the bodies and will aid in the formulation of effective control measures.

The studies, which it is the object of this paper to report, were made in the hope that further work on the gall tissues might reveal the true nature of the intracellular bodies, or might, at least, bring to light some parasitic organism. The work was undertaken at the suggestion of Dr. H. L. Lyon, to whom the writer is greatly indebted for notes on the disease and for a large quantity of preserved material collected in Fiji. The diseased tissues had been killed in several different fixing reagents and carried to seventy per cent alcohol. With so much excellent material at hand it was a relatively easy task to cut and stain a large number of microtome sections. In this paper, all cells that contain the bodies above mentioned will, for the sake of convenience, be referred to as infected cells.

Materials and Methods.

Galls were selected from all of the different collections. The material was brought through the higher grades of alcohol and embedded in paraffin in the usual manner. Soft tissues were cut into sections from five to ten microns thick; old, woody tissues were cut into sections from ten to twenty microns thick. The sections were stained with Delafield's haematoxylin or with Flemming's triple stain. The latter method gave the best preparations. The galls studied were from the cane varieties Demerara 117, Demerara 625, Demerara 1135, New Guinea 111, New Guinea 118, Badila, and Yellow Caledonia.

Figure 1. Cane plant suffering from Fiji disease as it occurs in the Philippine Islands. Stools from healthy and infected cuttings planted alternately in the row. The disease is readily transmitted by cuttings. Photograph supplied by Mr. H. A. Lee.

Observations on Diseased Tissues.

An examination of the tissues of the terminal buds of a number of diseased stalks has shown that groups of infected cells frequently occur a short distance back of the growing point. Here, in the phloem or in the tissues immediately adjoining the phloem, may be found small groups of cells that contain deep-staining, spherical or oval-shaped bodies. The bodies are conspicuous and easy to recognize in stained sections. The cells that contain them will give rise to the

galls that are so characteristic of Fiji disease. The groups of infected cells occur as elongated masses widely separated from each other by normal healthy tissues. The presence of the bodies in cane tips from infected plants, accounts for the readiness with which the disease is transmitted by cuttings. Text figure 1 shows stools from healthy and diseased cane planted alternately in the row. The severity of the disease may be judged by comparing the healthy and sick stools.

Successive stages in the formation of galls can be found in the young stalk tissue at different distances back of the growing point and in the young leaves of different ages. The earliest stages observed consist of very small groups of infected cells just below the growing point in the tissues that are in process of differentiating into vascular bundles. The infected groups can frequently be found in the procambium strands, far in advance of tracheids and sieve tubes. They have never been observed in the undifferentiated tissues of the bud. Similar groups of infected cells occur in the phloem of young leaves. The leaves produced at the growing point never show infection until after vascular bundles connecting them with the vascular system of the stalk have been formed. The fact that the youngest galls are always in the phloem tissues nearest the growing point seems to indicate that the disease-producing agent travels through the bundles. With the formation of each successive leaf it probably passes out along the veins, producing galls at irregular intervals. This method of infection would account for the fact that the galls are usually more numerous on the lower portions of leaves than on the tips. Small groups of infected cells in sections of young leaf tissue are shown in Plate 25, figures A and B. Two other small colonies are shown in figure C. The cells in the larger colony have started to proliferate. This represents a very early stage in gall formation. Somewhat older colonies are shown in figures D and E. It can be seen that the line of demarkation between diseased and healthy tissue is very sharp. The cytoplasm of infected cells is more dense and takes the orange stain more deeply than the cytoplasm in healthy cells. The bodies in the cells on the edges of the colonies are approximately the same size as those in the cells in the center of the colonies. There is no indication that the growth of the gall results from the passage of bodies from the original colony into the surrounding tissues. Increase in size seems to take place through the growth and proliferation of the cells of the original groups. How these cells become infected is not known. It is also not known why galls are more numerous in some leaves and stalks than in others.

Young galls are usually spindle shaped. They are sometimes short but are more often much elongated. They always occur on the under side of leaves, because they always arise on the phloem side of the bundle. They develop in the phloem or partly in the phloem, and partly in the surrounding tissues. The cells immediately surrounding the phloem, which in the healthy bundle would give rise to a sclerenchymatous sheath, are frequently infected. Occasionally some of the cells of the bundle sheath and of the fundamental parenchymatous tissue around the bundle become infected. In most cases, however, the infection is confined to the phloem.

Sections through diseased tissue showing progressive stages in the development of galls are pictured on Plates 25, 26, 27 and 28. The figures on Plate 25

show very early stages in gall formation. Figures A, B, C and D of Plate 26 give later stages. Figure E shows the beginning of lignification in the walls of the cells surrounding the infected tissues. The figures on Plates 27 and 28 show still later stages in the development of galls.

A study of sections through young galls shows that the colony of infected cells does not always arise in the center of the phloem. This may be seen by reference to figure A of Plate 26. In the bundle shown on the right, the colony is located in the upper right hand portion of the section of phloem. The colonies are often irregular in cross section, as is shown by figures A, B, C and D of the plate. In most instances almost all of the cells located within the limits of the young gall contain the deep staining bodies, but a few cases have been noted where a considerable number of these cells had escaped infection. Some young colonies have been observed to be made up of cells, more than half of which were free from infection. In such cases the uninfected cells occur in irregularly shaped groups scattered through the infected tissues.

The location, shape, and size of very young colonies, such as are shown in the figures of Plate 25 and in figure A of Plate 26, are apparently determined by primary infection. The size and shape of old galls are determined largely by the growth and division of infected cells. Figures A, B, C, and D of Plate 26 show different stages in the development of young galls.

After the gall reaches a certain stage of maturity a curious change takes place in the surrounding tissues. These tissues are derived from the cells that would ordinarily produce the sclerenchymatous sheath and, in some instances, from portions of the phloem. Many of the cells in these tissues enlarge and take on the appearance and staining reactions of tracheids. Their walls become thickened and lignified. Most of the thickening occurs as reticulate fibrous bands. The cells retain their shape but become hard and woody. This change in the cells surrounding the gall produces a woody covering which more or less completely encloses the infected tissues. The walls of the sheath are often quite thick but are usually broken by tissues that, for some reason, do not become lignified. The old gall is thus composed of two kinds of tissue: a soft inner tissue made up of elongated thin-walled cells, and a harder outer tissue made up of irregularly shaped, thick-walled, woody cells. In some galls there is a layer of thin-walled, uninfected cells between the inner infected tissue and the outer woody covering. Such a case is shown in figure C of Plate 28. Infected cells often adjoin the lignified tissues, as is shown in figure E of Plate 26 and figure A of Plate 27.

The variation in position and amount of infected tissue and in the extent to which lignification takes place causes the galls to show great variation in structure. This may be seen by reference to Plates 27 and 28. The gall shown in figure A of Plate 27 is only partly surrounded by lignified tissue. The cross section of woody tissue shown in figure B is U-shaped with the xylem elements of the bundle at the bottom of the U. The cross section of galls pictured in figure C shows other variations in structure. In figure D, the infected tissues are completely surrounded by many layers of lignified cells. The sections shown in figures A, B, and C of Plate 28 give still further illustrations of mature gall structure. It has been observed that a granular deposit sometimes occurs in the tissues of old galls. It

stains a deep violet with Flemming's triple stain and may entirely fill some of the cells. One of the most interesting characteristics of this deposit is that it is arranged in concentric layers around the central portion of the gall. In cross section the layers appear as concentric circles and as many as four of them have been seen in a single gall. They vary from one to several cells in thickness. The cells in the tissues between the layers may be free from the deposit or may contain it in small amounts. The nature of the deposit is not known.

Observations on Diseased Cells.

The infected cells of the youngest colonies are not very different in size and shape from the corresponding cells of the adjacent tissues. At a later time, when these cells begin to make abnormal growth and are stimulated to rapid division, they can no longer be identified with the cells of the tissues from which they arise. The cells in different galls vary considerably in size, but on the whole they are larger than the cells in the tissues from which they develop. They are much larger in old galls than in young ones. The smallest infected cells are found in half-grown galls that appear to be making rapid growth. While the cells in young galls are fairly uniform, those in old galls show great variation both in size and in shape. This fact becomes evident when the tissues shown on Plate 25 are compared with those shown on Plates 26, 27 and 28.

The nuclei in the infected cells of half-grown and mature galls are normal in appearance, except that in certain cells where the nuclei lie close to the deep staining bodies they are more or less crescent-shaped, like those shown in figures 25 and 31 of Plate 24. The nuclei in very young galls and in the outer cells of somewhat older ones sometimes contain two or more nucleoli and are frequently lobed like those shown in figures 29 and 30. The nuclei in a few layers of the uninfected cells surrounding young galls are often lobed in the same way. It was at first thought that this might represent stages in direct nuclear division, but further study has led to the conclusion that it is a pathological condition from which the nucleus later recovers, and that it is in no way related to nuclear division. The lobing may be due to the production of some toxic substance by the intracellular bodies. There is no evidence of direct nuclear division in infected gall cells. Stages in mitotic division have been observed in a number of sections, but they are not abundant in any of my material. Dividing nuclei are shown in figures 24 and 26 of Plate 24. The stage of division shown in the figures is the one most commonly seen. Infected cells usually contain only one nucleus, but binucleate cells have occasionally been found in old galls. Stages in the division of host cells by cell plate formation have been observed. This division often gives rise to two infected daughter cells such as are shown in figure 25. The infected cells of young galls are thin-walled and more or less elongated. They are rich in protoplasm, and in their staining reactions resemble the cells in meristematic tissues. The cytoplasm in the cells of young galls is more dense than that in the cells of surrounding tissues, and much more dense than that in the cells of old galls. The infected cells of old galls appear to be dead.

Observations on the Intracellular Bodies

The intracellular bodies associated with Fiji disease present many different appearances, but are always easy to distinguish from cell organs by the avidity with which they take the analine stains. In young galls they appear to occupy a vacuole in the cytoplasm of the host cell. In most instances the vacuole is somewhat larger than the body and is therefore easy to distinguish. In some cases, however, the host cytoplasm is so closely applied that it is not possible to determine whether the body lies in a vacuole or is suspended in the protoplasm. The walls of the vacuole are clearly shown in figures 21 and 31 of Plate 24. They are not so plainly shown in some of the other figures.

The bodies take many different positions in the host cell. They often occur near the nucleus, but do not come in contact with it. On the whole they are much larger and occupy a greater proportion of the cell lumen in old galls than in young ones. Although relatively large and relatively small bodies may be found in different cells of the same gall, most of the bodies in a given gall are rather uniform in size. Their average size varies considerably in different galls. By measuring the bodies along their greatest diameter it will be found that they vary in different galls from an average of about 5 microns to an average of as much as 25 or 30 microns. During the early stages in the growth of the gall, the the size of the bodies does not seem to be determined by the age of the gall. The bodies in some of the very young galls are large, while those in older galls are frequently quite small. It has been observed that the bodies of smallest average size are to be found in those galls that seem to be making most rapid growth. Usually only one body occurs in each diseased cell. In some galls, however, two or more of them are present in many of the cells. Cells containing more than one body are shown in figures 21, 24, 26, 27 and 32 of Plate 24.

There is good evidence that the bodies divide. A number of cases have been found where they seem to be in process of division. Before division the body takes a position near the host cell nucleus. It divides in a plane parallel to the short axis of the host cell. It becomes much elongated and divides by constriction. Unfortunately the earlier stages in this process have not been observed. A late stage such as is shown in figure 28 is fairly common in young galls. That division of the bodies is common in some of the young galls is indicated by the large number of cells containing two of them. Such a cell is shown in figure 27. Occasionally cells are found that contain more than two bodies but the number is never very large. The fact that some cells contain three or more bodies suggests that the division of a body is not always immediately followed by host cell division. When two bodies occupy the same cell, they are, in most cases, approximately the same size and are located on opposite sides of the host cell nucleus.

The bodies shown in figures 1 to 14 and in figure 18 are all from young galls. It will be seen that they are composed of a deep staining granular material and have a coarse reticulate structure. Many of them contain vacuoles like the ones shown in figures 5, 7 and 8. Some contain fairly large, deep staining granules, such as are shown in figures 3, 4, 5 and 6. Many have one or more appendages which are usually rather short, with blunt rounded ends. The appendages are frequently, but not always, more hyaline than the main part of the

body. Sometimes they are long, rather slender, and show a wavy outline. Such a case is pictured in figure 13. The bodies shown in figures 9, 10, 11 and 12 are typical for young galls. The one shown in figure 10 is a very common form. Those shown in figures 14 and 18 are less common, but by no means rare. Many of the bodies are spherical or oval in shape and do not have appendages.

As the gall nears maturity the bodies take on a somewhat different appearance. They become less dense and gradually lose the reticulate structure which is so typical of the early stages. At this point in the development of the gall many of the bodies contain one or more organs that resemble nuclei. Two of these are shown in figures 15 and 16, and others are shown in figure 22. This organ is approximately spherical, is surrounded by a rather thick membrane and contains a central, more or less spherical granule which stains a deep red color with Flemming's triple stain and resembles rather closely a nucleolus. Since however these organs occur in large numbers in some of the bodies, are by no means uniform in size, have never been observed in process of division and are not present in the bodies in young galls, they are not thought to be nuclei. It has not been possible to distinguish nuclei in the bodies during their division.

The bodies in old galls do not contain nuclear-like organs, and differ in many ways from those in young galls. They do not show a reticulate structure, but are filled with granules of many different sizes. The granules occur in masses of considerable density in the inner parts of the body, which is often surrounded by a hyaline outer plasma. Such bodies are usually much elongated and fill a considerable part of the host cell. It is characteristic of the bodies at this stage to show a cleft at one end such as is pictured in figure 19, or a split such as is shown in figure 20. Some of the bodies in old galls are extremely vacuolate like the one shown in figure 23. It has been observed that the contents of the bodies in old galls may sometimes become divided, as is shown in figure 17. The separate portions round up and take on the appearance of cysts. The manner in which this division occurs has not been determined, as stages in the process have not been observed. The breaking up of the contents of the old body is the nearest approach, so far as observed, to anything that might be looked upon as spore formation.*

Discussion

This study of the galls of Fiji disease has not yielded sufficient evidence to justify a decision as to the nature of the peculiar intracellular bodies associated with the disease. The fact that the bodies are capable of division and appear to grow, indicates that they belong to a parasitic organism. Their distribution in the gall tissues, apparent manner of spreading, and constant association with the earlier stages of gall formation give further support to this view. In the possession of pseudopodia-like appendages and in structure they resemble certain amoebae. The granular materials contained in the bodies in old galls are somewhat like the "lichtbrechende Körnchen" described by Bütschli[3] in his discussion

*Since this paper was prepared for publication, there appeared in the Philippine Agriculturist an article on Fiji disease by Mr. F. P. McWhorter. This author claims to have germinated the bodies associated with the disease. If he could prove that the amoebae which occasionally appear in his cultures actually result from the germination of the bodies of Fiji disease, he would make a very important contribution to our knowledge of this obscure malady.

of the protoplasmic contents of Rhizopods. Many of the bodies present forms which suggest that they are not waste products. Moreover, the Fiji disease is known to be infectious and there is no evidence of the presence of any other causal agent. The mitotic division of the nuclei of infected cells indicates that such cells are not in process of degeneration and is evidence in favor of the view that the bodies represent an organism. Mitotic nuclear divisions occur in the infected cells of the galls caused by *Plasmodiophora brassicae* Wor.[8], *Spongospora subterranea* (Wallroth) Johnson[7], *Chrysophlyctis endobiotic* Schilb[2], and other intracellular parasites. However, the bodies do not resemble, either in morphology or in staining reactions, any of the parasites belonging to the Plasmodiophoraceae or the Chytridineae. Whether they are inert cell inclusions resulting from some physiological disturbance or degenerative process associated with the disease, or represent a new type of plant parasite is a question which can not be definitely answered at this time.

The studies here recorded have not shown a relationship between this and any other known plant disease. Many of the gall diseases of plants, and especially those that involve the above-ground parts, are due to the work of various insects. But in the case of Fiji disease, there is no evidence that an insect is concerned, except perhaps as a means of transferring the disease from one plant to another. Insect galls arise separately or are at least local in their distribution. This is due to the fact that each gall is caused by a separate attack. Fiji disease differs strikingly from such troubles as these in that it is systemic in the tissues of its host plant, the causal agent apparently spreading through the vascular tissues.

The galls of Fiji disease always originate in the phloem, and although the disorder affects other tissues to a certain extent it must be looked on as a phloem disease. In this respect it resembles some other well-known plant diseases, such as the leaf roll disease of the potato, the sieve tube disease of Liberian coffee, and the brown bast disease of *Hevea brasiliensis*. These three diseases manifest themselves by necrosis in the phloem, while Fiji disease causes abnormal growth and cell proliferation in certain definite and well-defined parts of the phloem. Intracellular bodies such as are associated with Fiji disease are not known in the case of these other phloem troubles. It is worth noting, however, that the diseased cells in the phloem of the potato "become filled with a granular or globular deposit",[1] that the young diseased sieve tubes of the coffee tree "Zijn met wondgom opgevuld"[14], and that "numerous minute golden yellow spots of irregular outline"[6] are present in the diseased phloem of the Para rubber tree. If Fiji disease caused necrosis instead of stimulating growth and cell division it might be difficult to distinguish the intracellular bodies from disintegrating protoplasm.

It should be pointed out here that there are certain analogies between the Fiji disease and the Mosaic disease of sugar cane. Both are infectious systemic diseases, and both affect stalk and leaf tissues. There is a marked similarity between the distribution of the galls on the leaves of cane suffering from Fiji disease and the distribution of the light colored elongated spots on the leaves of cane infected with mosaic disease. This suggests that the two diseases may spread through the host plant tissues in a similar manner. The Fiji disease galls and the Mosaic disease spots or lesions both originate in the tender young tissues above and below the terminal bud of the stalk.

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FURTHER STUDIES ON THE INTRACELLULAR BODIES ASSOCIATED WITH CERTAIN MOSAIC DISEASES

By L. O. Kunkel

In a former paper[3] the writer described and pictured intracellular bodies that were found to be associated with the mosaic of corn. Since the bodies were found in the cells in the light green portions of the leaves and in the necrotic tissues of the stalk, but were never observed in the cells of healthy plants or in the dark green portions of diseased leaves, it was suggested that they might be of etiological significance. The relation of the bodies to their host cell nuclei as well as their structure and staining reactions suggests that they belong to a living organism. If, however, there is a causal relationship between the bodies and the disease, it is natural to expect that they are associated with other mosaic diseases as well as that of corn. The finding of amoeboid bodies in the cells of mosaic plants of *Hippeastrum equestre* Herb. has already been reported.[4] It was in the hope of gaining further knowledge of the cytological aspects of the virus disease problem that several different mosaic diseases were studied during the past year. In the course of this work the writer has succeeded in demonstrating that bodies similar to those of corn and Hippeastrum mosaic are associated with the mosaic diseases of Chinese cabbage, *Brassica pekinensis* (Lour.), Gagn., sugar cane, *Saccharum officinarum* L., and tobacco, *Nicotiana Tabacum* L. No attempt will be made at this time, however, to describe in detail the bodies found in the cells of these three plants. The chief object of the present paper is to describe the mosaic of Hippeastrum, and the bodies that are associated with this disease.

Hippeastrum equestre is commonly grown in yards and flower gardens in Honolulu. It has escaped from cultivation in several places and is now growing wild in some of the valleys above the city. At one place in Kalihi Valley there are thousands of these plants growing along an old road and in an abandoned field. Most of the plants used for study were obtained from this valley.

A mosaic disease is present on both the cultivated and wild plants. It causes a typical mottling of the leaves, but the pattern is somewhat different from that of corn mosaic. A healthy and a diseased leaf are shown in text figure 1. It will be seen that the light green areas occur as irregularly shaped blotches and that the edges of the blotches are sharp and definite. It has been noted that the contrast between the light and dark green areas is greatest for the leaves of plants that have been growing in the shade, or have been growing where they were shaded at least a considerable part of the day. The healthy portions of such leaves develop a darker green color than the healthy parts of leaves that grow in full sunlight.

Badly diseased plants are somewhat stunted and do not produce flowers of normal size. The mottling is usually confined to the leaves. Numerous cases have been observed where the flowers and flower stalks of diseased plants appear to be entirely healthy. In some instances, however, the flower stalk, which is always green in color, is more or less mottled and distorted. It is a rather fleshy

organ and the deep green parts occur as raised areas or warts on the smooth surface of the lighter green tissues. These green warts, although not large, are somewhat similar in appearance to the warts that occur on cucumbers suffering from mosaic disease. Each flower stalk normally bears three flowers. The flowers may also show the disease. The expanded portion of the perianth of a healthy flower is orange vermilion in color. The perianth segments of diseased flowers are blotched with irregularly shaped areas of a light madder purple. Such

Figure 1—*Mosaic of Hippeastrum.* A healthy and a diseased leaf.

flowers are frequently dwarfed and distorted. In some cases all three of the flowers on a diseased stalk are mottled, while in other instances one, two, or all of them appear to be healthy. No evidence of disease has been found in the non-green portions of the bulb. This mosaic is probably the same disease which attacks tulips, narcissi and hyacinths, and which has been described by Griffiths.[1]

So far as observed the young bulbs from diseased Hippeastrum plants always give diseased plants. Just how the disease spreads to healthy plants is not known, but it is probably transmitted by insects. During the past year a number of plants

were grown in flower pots. Some of the healthy ones were kept in insect-proof cages, while others were kept outside at a short distance from diseased plants. All of the plants kept in cages remained healthy, while most of those kept outside contracted mosaic disease. Several unsuccessful attempts were made to transmit the disease by means of the corn aphid. This insect is unable to live for more than a few days on Hippeastrum plants and apparently cannot transfer the Mosaic.

In making a study of the bodies associated with Hippeastrum mosaic a considerable quantity of both diseased and healthy leaf tissue was killed in various

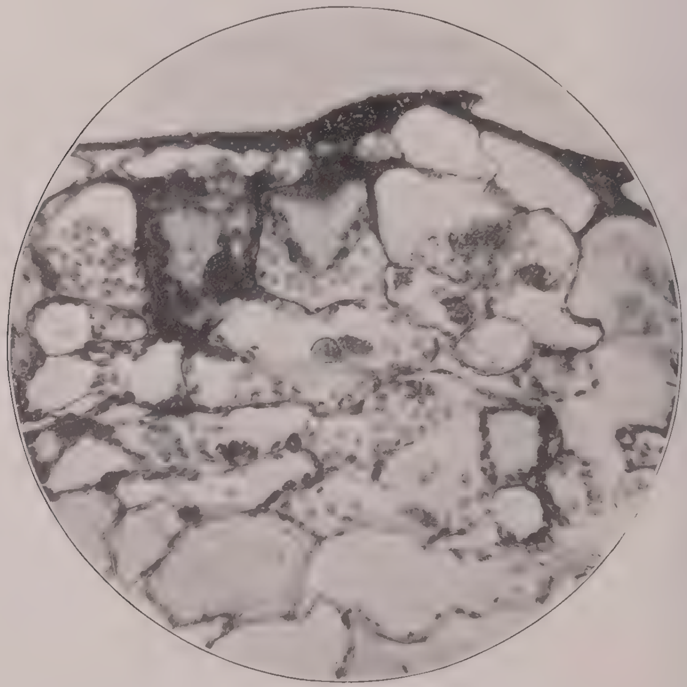

Figure 2—*Mosaic of Hippeastrum.* A section through the upper part of a diseased leaf. × 200.

fixing reagents, but mostly in Flemming's weaker solution, which gives excellent results. The material was carried through the different grades of alcohol and xylol and embedded in paraffin. It was cut by means of a microtome into sections varying from five to twenty microns in thickness, mounted in the usual way and stained with Flemming's triple stain. The cells in the mature leaves of *Hippeastrum equestre* are rather large. The tissues are succulent and well suited for cytological study. They furnish the best material that has thus far been found for making observations on the bodies associated with mosaic disease. When sections of mature diseased leaf tissue of Hippeastrum plants are properly stained the intracellular bodies associated with this mosaic disease stand out with great clearness and sharpness. In order to show the size, shape and structure of the

bodies and their relation to the host cell nucleus a few photographs and drawings have been made.

The bodies vary greatly in both size and shape even in the same tissue. In general they are somewhat smaller in Hippeastrum than in corn. They are usually larger in large host cells than in small ones. Text figure 2 is a photograph of a section through the upper part of a diseased leaf. In the cell in the center of the picture will be seen a nucleus with an amoeboid body closely applied to its surface. The outline of the nucleus is much sharper than that of the body. Most of the chloroplasts in this cell are grouped along the cell walls.

The bodies of Hippeastrum mosaic show a special affinity for the Orange G stain, and have a structure very similar to that of protoplasm. They are usually located near, or in contact with, the host cell nucleus. That they take many different positions on the nucleus is well shown by figures A to K, Plate 29. Figure A shows a small section of tissue from the upper part of a diseased leaf. Three infected cells lie just beneath the epidermis. In two of these the bodies are attached to their host cell nuclei. In the other infected cell the body lies close to, but not in contact with the nucleus. Nuclei which have bodies attached to them appear to be diseased. Their chromatin does not stain like that in the nuclei of normal cells and they are often considerably distorted. They are usually flattened or even somewhat indented at the point of contact with the body. They are sometimes crescent-shaped like the nucleus shown in figure C. In such cases the foreign body always lies in the sinus of the crescent. Nuclei which have become more or less flattened or indented are shown in figs. E, F, G, I, J, N, O and P. The bodies in some cells are elongated and extend from the host nucleus to the cell wall, as is shown in fig. H. In other instances they are attached to the cell wall but do not come in contact with the nucleus. Such a case is shown in fig. Q. Although the typical position of the body is on the host cell nucleus it is frequently found in other positions. The bodies shown in figs. B and D are suspended in the protoplasm at some distance from their host cell nuclei. In a few cases bodies have been found which appear to be in contact with one or more chloroplasts. In general, however, they keep at some distance from the plastids.

The bodies show a very definite structure. It is usually finely reticulate like that of protoplasm. The meshes of the reticulum appear to be filled with a rather transparent homogeneous substance, that is not readily stained. No evidence has been found of a membrane surrounding the bodies. They seem to be in direct contact with the protoplasm of the host cell and have never been seen to occupy a vacuole. One or more deep staining granules have occasionally been observed in the bodies. The granules do not look like nuclei and it is not believed that they represent such organs. Many of the bodies contain one or more vacuoles such as are shown in figures N and P. Vacuoles often occupy a central position. Typical cases of large central vacuoles are shown in figures E, G and Q.

From this description and from the pictures it will be seen that the bodies of Hippeastrum mosaic are very much like those associated with the mosaic of corn. This is especially true as regards structure and staining reactions. They are also similar in shape and occupy similar positions on their host nuclei. In

Hippeastrum, however, they have never been observed to surround or engulf the nucleus. Perhaps this is because they are smaller than the bodies of corn mosaic. Another point of similarity is to be found in their distribution in the tissues.

The bodies of Hippeastrum mosaic are always present in cells located in the light green portions of the mature leaves of diseased plants. They have not been found in the cells of the very young leaves. These leaves show the mosaic pattern before the bodies can be observed in their cells. If bodies are present, they are either too small or too transparent to be distinguished from the protoplasm of the cell. After mosaic leaves have reached one-half to two-thirds of their normal size the bodies appear in the cells of their light green colored tissues. At this stage in the growth of the leaves the bodies are quite small like those shown in figures M and O. In Hippeastrum, the mosaic pattern shown on the upper surface of any leaf is usually different from that on the under surface of the same leaf. It often happens that the lower part of a section through a diseased leaf is a normal green color, while the upper part of the same section is a light green color. When such sections are stained it is seen that many of the cells in the upper part of the leaf contain the amoeboid bodies, while the cells in the lower part are entirely free of them. Mature leaves often show several different shades of green color, i. e., the deep green of healthy portions, the very light green of badly diseased portions, and intermediate shades of green. In such cases the bodies in the cells of the very light colored tissues are larger than those in the cells of tissues that are a darker green. In general it may be said that the average size of the bodies in any tissue is in direct proportion to the degree of chlorosis. The largest bodies are always found in the most chlorotic portions of the older leaves of the plant. They have been found in the cells of all parts of the leaf except the vascular tissues. It is an interesting fact that they are not contained in all of the cells of any tissue. A considerable number of cells remain uninfected even in the most chlorotic parts.

While no attempt will here be made to fully describe the bodies found in the mosaic tissues of Chinese cabbage, sugar cane, and tobacco, a brief statement regarding them may be of interest. In each of these plants the amoeboid bodies are quite similar to, but somewhat different from the bodies associated with mosaic in corn and Hippeastrum. In the leaves of the Chinese cabbage they reach about the same size that they do in the leaves of Hippeastrum. They are usually not in contact with the host nucleus and may occupy any part of the cell. They frequently have a number of chloroplasts clustered around them. In structure and in staining reaction they are similar to the bodies of corn mosaic. The bodies associated with sugar cane mosaic tend to stain more deeply than do those in any of the other plants studied, and are more irregular in shape, as is shown by figure R. The figure also shows the position of the body on its host nucleus. This is quite similar to the positions which are typical for the bodies in both corn and Hippeastrum. Because of the fact that the older tissues of the sugar cane plant become very hard they are not suitable for cytological studies. Satisfactory sections showing the bodies of cane mosaic have been made from stalk tissue only. The best sections were obtained from tissues a short distance back

of the growing point. Young stalk tissue of the varieties Striped Tip and Yellow Caledonia have given the best results.

After having found intracellular bodies associated with mosaic disease in corn, Hippeastrum, Chinese cabbage, and sugar cane, a study was made of stained sections of healthy and mosaic tobacco leaves. In some of the sections of mosaic leaves, bodies similar to those described in corn and Hippeastrum may plainly be seen. In morphology, structure, affinity for Orange G stain, and position in the host cell, they are much like the bodies found in the cells of the other plants. Figures L and S show two of the bodies of tobacco mosaic. The one in figure L is attached to its host cell nucleus; that in figure S lies close to, but not in contact with, the nucleus.

In a recent paper Palm[5] has described certain "amoebiform corpuscles" which he finds in mosaic tobacco leaves. He apparently considers these bodies to be analogous to those of corn mosaic. In addition to the "larger foreign corpuscles," which he says "lie either in intimate contact with the nucleus or more or less in its vicinity", he finds numerous extraordinarily small granules which, he thinks, may represent an organism. On the assumption that the granules are alive and that they are the same bodies which Iwanowski described as bacteria, he gives them the name *Strongloplasma iwanowskii.* The writer's cytological studies on tobacco mosaic lead him to conclude that the intracellular bodies which he finds associated with mosaic disease in tobacco and other plants are undoubtedly the same organs which Palm has described as "amoebiform corpuscles" and which Iwanowski[2] described as "Plasmaanhaufungen". That Iwanowski considered the possibility of these bodies representing a living organism which might be responsible for the disease, is shown by the following statement: "Wie hierbei, so auch bei der Untersuchung an lebenden Blättern drängte sich oft die Frage auf, ob diese Plasmaanhaufungen nicht irgend eine Amoeba vorstellen, welche die wirkliche Ursache der Krankheit sein könnte". In another place he says, "Aber Amoeben können nicht ein Bakterienfilter passieren; der Mikrob der Mosaikkrankheit kann nur ein feinstes Körnchen sein." In considering the intracellular bodies as a possible cause of mosaic disease, the writer meets the same difficulty which prevented Iwanowski from looking on the "Plasmaanhaufungen" as causal organisms. They are too large to pass through bacterial filters. Iwanowski did not know, however, that these bodies are associated with mosaic disease in several different plants. Perhaps this further evidence may justify an attempt to harmonize statements which at first appear to be contradictory. It may be that the amoeboid bodies associated with mosaic disease represent only one stage in the life of a causal organism. At another stage they may be so small and plastic that they can pass through the fine pores of a filter and escape detection under the microscope. They probably become visible only after a certain period of growth within the host cell. Much further work will be necessary before arriving at definite conclusions in this regard. For the present, we must be content with the knowledge that intracellular amoeboid bodies accompany mosaic disease in several different plants; that these bodies look like living organisms, and that in corn and Hippeastrum they are associated with chlorosis in such a way as to account for the mosaic pattern in the leaves.

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STUDIES ON THE MOSAIC OF SUGAR CANE

By L. O. Kunkel

Mosaic is recognized as one of the serious diseases of sugar cane in Hawaii. How and when it reached this territory is not definitely known; it was first observed here in 1908. At the present time it is prevalent on all of the sugar-producing islands and on most of the plantations.

During the past three years, the writer has been studying this mosaic in the hope of gaining further information as to the nature of the disease, the ways in which it spreads, its different host plants, the damage it does to the sugar cane crop, its effects on different commercial varieties, and the means by which it may be controlled. The object of the present paper is to record observations on the disease and to give the results of some of the experiments that were made.

Nature of the Disease

The mosaic of sugar cane has been so well described by Wakker and Went[8], Wilbrink and Ledeboer[9], Lyon[6], Brandes[1], and others, that any further general description seems unnecessary. It does not closely resemble any of the other known cane diseases and may readily be recognized by those familiar with the literature. The writer's object in further describing and illustrating it is to emphasize certain facts that seem important to an understanding of the nature of the disease.

Observations were made on mosaic plants of many different unnamed varieties and on the following commercial varieties: Lahaina, Hawaii 109, Demerara 1135, Demerara 117, Yellow Tip, Striped Tip, Badila and Yellow Caledonia. The list includes resistant as well as susceptible varieties. The disease was studied in cane of different ages up to two years and in both plant and ratoon crops.

Chlorosis of the leaves is the most striking symptom of mosaic. It consists in irregularly shaped, light yellowish-green colored areas distributed throughout the normal green tissue. This gives rise to a pattern which differs somewhat from leaf to leaf, but which is more or less characteristic for any given variety. As far as has been observed, the pattern on the upper surface of a leaf is exactly the same as that on the lower surface.

The pattern shown by the leaves of most plants afflicted with mosaic is already present when the young leaves unfold and begin to turn green. For this reason it is in most cases not possible to determine how the chlorotic areas arise. In the case of sugar cane, however, the pattern shown by old leaves is usually not present on young ones and it is, therefore, possible to observe the chlorotic areas in process of formation. It has been observed that they begin as small spots scattered about over the leaf. The spots grow and finally include much tissue that was at first a normal green color. In their growth, the spots that happen to be close together coalesce and form chlorotic areas of various sizes and shapes. While the areas resulting from the fusion of two or more spots are quite irregular in shape, the spots themselves show considerable regularity. They are usually

elongated and somewhat oval shaped. Text figures 1, 2, 3 and 4 show photographs of parts of leaves of different ages taken from a diseased plant of the variety Lahaina. Figure 1 shows part of a young leaf. The portion on the left of the midrib, which in this leaf was the last part to unfold, shows the chlorotic spots in an early stage of formation. It will be seen that the spots vary somewhat in size. The smallest ones are probably the youngest. Figure 2 was made from

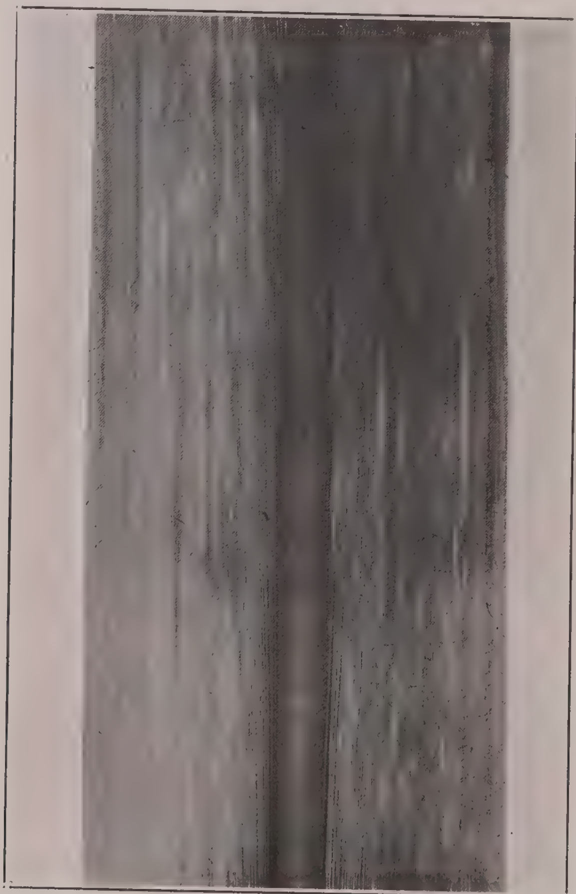

Figure 1—*Mosaic on Lahaina.* A young leaf showing an early stage in the development of chlorotic spots.

part of a leaf a little older than that shown in figure 1. Most of the spots on this leaf are larger than those of figure 1. Some of them have already coalesced. A section from a still older leaf is shown in figure 3. Here the spots are much larger than those on the younger leaves. Figure 4 shows part of a mature leaf. The spots have enlarged and fused together to such an extent that irregularly shaped chlorotic areas have been formed. Here it is no longer possible to dis-

tinguish the individual spots from which they are derived. It is in this way that the mosaic pattern is produced.

By marking off portions of very young leaves and carefully drawing to scale the individual spots, using the varieties Striped Tip and Hawaii 109, it has been possible to prove that the spots slowly increase in size and frequently fuse to-

Figure 2—*Mosaic on Lahaina.* A young leaf showing chlorotic spots that are somewhat larger than those pictured in Figure 1.

gether. In text figure 5 the long stripe running parallel with, and close to, the midrib on the left side of the leaf consisted of three distinct spots on June 26. Fifteen days later, when the leaf was photographed, the spots had fused together to form the stripe shown in the picture. The distance between the two lower spots was four and one-half millimeters on June 26. During the two weeks that the leaf was kept under observation, the spots gradually elongated. While a part of this enlargement was due to the growth of the leaf, most of it resulted from the spread of chlorosis to the normal green tissues bordering the spots.

Most of the spots which later made up the chlorotic areas are already present on the leaf when it first becomes green. It has been observed, however, that new spots sometimes arise in the normal green tissue as leaves unroll from the spindle. The new spots arising in green tissue remain rather small, but in other respects are exactly like the older ones. They begin as small, circular, slightly elongated,

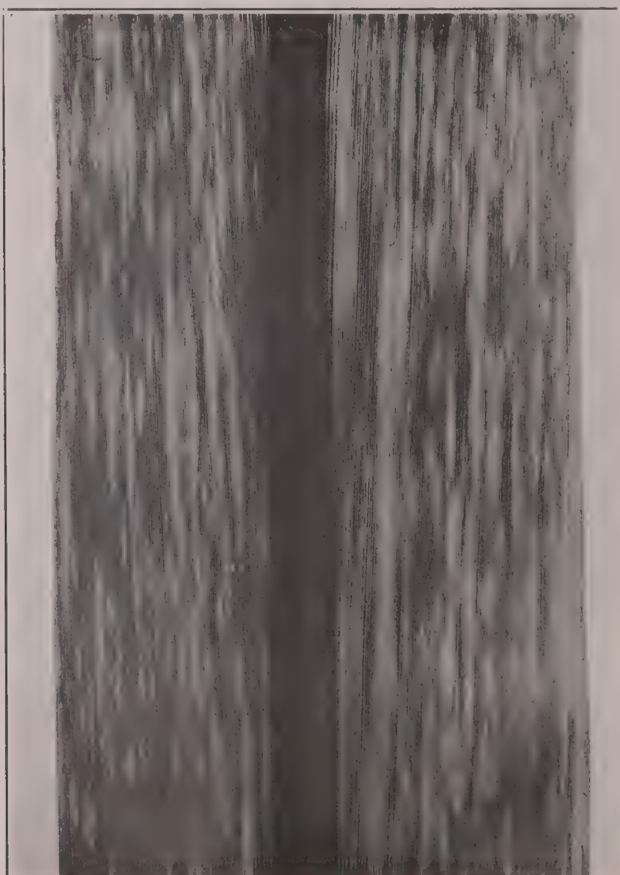

Figure 3—*Mosaic on Lahaina.* A mature leaf showing chlorotic areas that result from the fusion of individual spots.

yellowish colored specks, not more than one-half millimeter in diameter. They slowly enlarge. One such spot that was kept under observation reached a length of six millimeters.

There is not much regularity in the distribution of the spots on the leaves. There is, however, a tendency for them to be grouped end to end along certain veins. When spots grouped in this way coalesce, they produce long stripes such as are shown in the section of leaf of the variety Striped Tip, which is pictured in text figure 6. The chlorotic areas may also be grouped entirely or mostly on one side of the midrib, a large portion of the leaf remaining apparently healthy. Such

a case is shown in text figure 7. In other instances, the chlorotic areas are grouped along either side of the midrib, as is shown in text figure 8, and cases can be found where they are grouped along one or both edges of the leaf. In most instances, however, the chlorotic areas are distributed over the entire leaf, as is shown in text figure 9.

Figure 4—*Mosaic on Lahaina.* An old leaf showing the pattern that results from the fusion of individual chlorotic spots.

The average size of the light green areas varies with different varieties of cane. They are usually large on the varieties Striped Tip, Yellow Tip and Badila. They are relatively small on the varieties Lahaina and Hawaii 109. The patterns shown by mature leaves are determined by the number, size and distribution of the spots that were present when the leaves were young. Figures 2, 3, 4 and 5, Plate 30, show some of the patterns that are common on leaves of the variety Striped Tip. Figures 7 and 8 of the same plate show patterns common on leaves of the variety Hawaii 296. Figure 1 of the plate shows part of a young leaf of the

variety Striped Tip, while figure 6 shows part of a young leaf of the variety Lahaina. These pictures bring out the fact that spots on young leaves of the variety Lahaina are much smaller than those on the young leaves of Striped Tip.

It has frequently been observed that the central areas of some spots are a normal, green color and that only the borders are markedly chlorotic. Several spots with green centers are shown in figure 1 of Plate 30. Sometimes a small elongated chlorotic spot lies in the center of the green area. In other instances the green area is surrounded by two concentric bands of chlorotic tissue. The

Figure 5—*Mosaic on Striped Tip.* The chlorotic stripe shown on the left side of the picture, close to the mid-rib, consisted of three distinct spots two weeks before the picture was taken.

bands or zones of light green tissue are separated either by normal green tissue or by tissue that is less chlorotic than that of the bands. It is an interesting fact that the spots on certain plants show this zonation while the spots on other plants of the same variety growing under similar conditions show no zonation. Banded spots have been observed on plants of several different seedling varieties and on the commercial varieties Striped Tip, Yellow Tip, Hawaii 109 and Badila. A portion of a leaf of the variety Badila, having spots with green centers and showing in some of these green centers small, centrally located, elongated, chlorotic areas, is pictured in text figure 10. Similar zonated chlorotic spots also occur on diseased leaves of Sudan grass and wonder forage grass. The banded spots

call to mind the Liesegang rings produced by chemical reactions in plates of gelatine or of other colloidal substances.

One of the interesting characteristics of the chlorotic areas on young leaves is that the shade of color on leaves of the same age is approximately the same for different individual plants and even for different varieties. On old leaves, however, there is considerable variation in the shade of color shown by the chlorotic

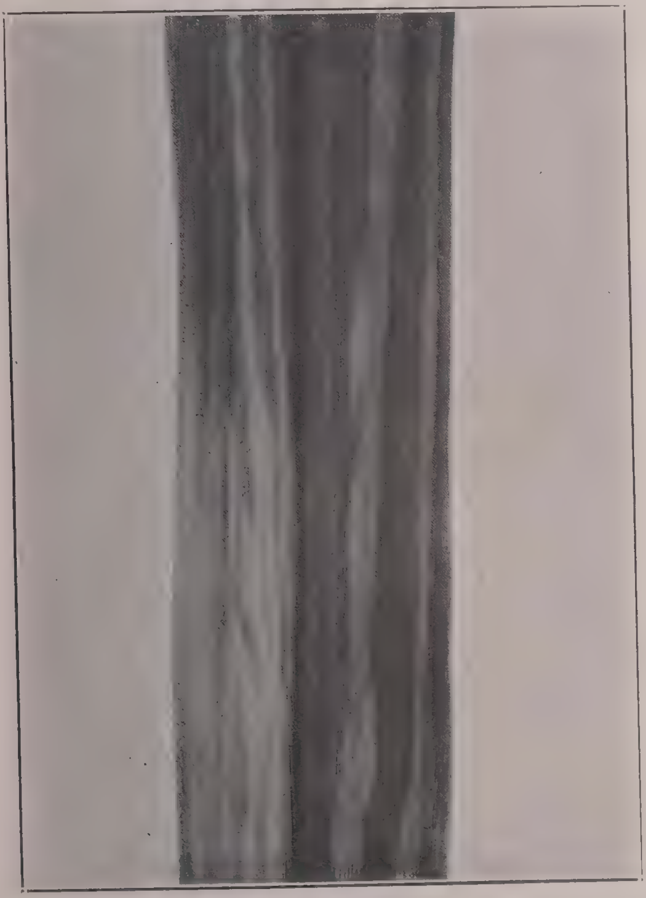

Figure 6—*Mosaic on Striped Tip.* The fusion of chlorotic spots grouped end to end along certain veins produces the long stripes shown in the photograph.

areas on different varieties. The old leaves on most of the varieties studied have small white or very light greenish yellow spots in the chlorotic areas. These light colored spots and streaks have been described by Brandes.[1] In figure 4 of Plate 30, they are shown on a portion of a leaf of the variety Striped Tip.

In addition to the white or very light greenish-yellow colored areas, the chlorotic portions of old leaves of certain varieties show dead areas that have a characteristic brownish color. These areas have been described by Lyon[6] for the

varieties Hawaii 27, Hawaii 207 and Hawaii 296, and by Miss Wilbrink[10] for the varieties 247 B and Black Cheribon. The writer has observed them on the variety Lahaina.

In other varieties, the light greenish areas, instead of deteriorating as the leaf ages, have a tendency to recover. They may become so green that it is difficult to distinguish them from areas of normal green color. This has frequently been

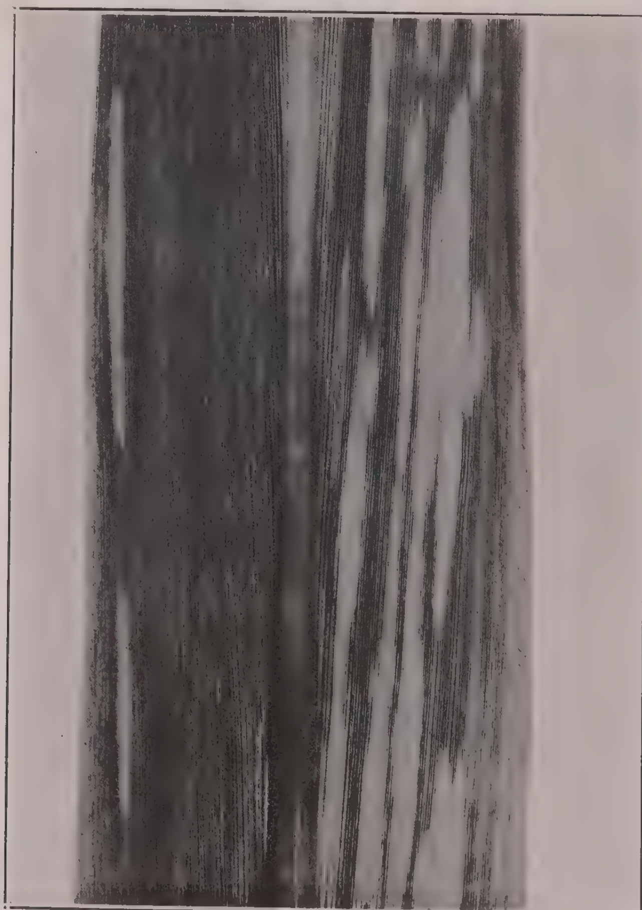

Figure 7—*Mosaic on Striped Tip.* A mature leaf, showing how chlorotic spots are sometimes grouped on one side of the midrib.

observed to occur on old leaves of the varieties Hawaii 109 and Demerara 1135. The line separating chlorotic from normal green tissues is quite sharp and definite in the case of young leaves, but on older leaves there is a more or less gradual fading out of the green color in the tissues between normal green and light green areas. The sharpness of the line of demarkation between normal and light green areas varies with different varieties. It is much more distinct for the variety Striped Tip than for Lahaina, as may be seen by reference to text figures 4 and 8.

Although chlorosis of the leaves, as above described, is the most striking symptom of mosaic, the disease usually causes more injury to the stalks than to the leaves. The markings and cankers produced on the stalks have been described by several different authors. The tissues in the rind of the stalks of certain cane varieties contain coloring matter. The mosaic markings are due in many cases to a partial or total absence of color in the cells in certain portions of the rind.

Figure 8—*Mosaic on Striped Tip.* A mature leaf showing chlorotic areas grouped along both sides of the midrib.

The disease affects the substance causing the red or purple color in much the same way that it affects the green coloring matter in parts of the leaves. In the case of varieties that do not have colored stalks, the diseased areas may be distinguished by an ashy gray color that develops in parts of the outer tissues of the rind.

In addition to the markings resulting from color changes, diseased stalks often show irregularly shaped, elongated, dead areas. These areas are usually small, but in some varieties they reach considerable size. They may occur on all

of the mature internodes of the stalk. More often, however, they are to be found only on the internodes of the middle or upper part of the stalk. Although the cankers do not occur on all stalks, they are a very common symptom of the disease. They have been found on diseased stalks of all of the commercial varieties studied. They occur on stalks growing under favorable conditions as well as on stalks growing under unfavorable conditions. Text figure 11 shows

Figure 9—*Mosaic on Striped Tip.* A mature leaf showing chlorotic areas distributed over its surface.

cankers on portions of two stalks of the variety Lahaina. Pieces cut from a healthy and a diseased stalk of the variety Badila are pictured in text figure 12. The elongated lesions on the diseased stalks are plainly shown. When the cankers are numerous and large, the stalk shrivels and is badly damaged.

The lesions caused by the disease occur not only in the rind but in the deeper tissues as well. Matz[7] must be given credit for first describing the inner lesions, and for recognizing that they are a result of the disease. Lyon[6] has reported

masses of discolored tissue in sticks long affected with the disease and has shown them in a photograph of a stalk of the variety Demerra 115. Other workers have not observed these internal discolorations and lesions to be a symptom of the disease. In referring to Lyon's observations on Demerara 115, Miss Wilbrink, in a recent publication, says, "Als een symptoom van Strepenziekte nam ik dit laatste verschijnsel hier nog miet waar; wel doet het zich hier veel voor bij het oudere riet, wanneer dit in groei gaat stagneeren".

Figure 10—*Mosaic on Badila.* A mature leaf showing banded chlorotic areas.

According to the writer's observations, discoloration and necrosis in mature inner stalk tissue is a constant symptom of the disease. It occurs in the diseased stalks of all the varieties studied. It must be recognized, however, that the relatively large internal brown masses of tissue and the internal lesions represent a late stage in the development of the disease within the stalk. In the inner, immature tissues of the internodes of diseased stalks, small, opaque, whitish, elongated pockets of tissue may be observed. Without, at this time, attempting to give a detailed description of the changes that take place in the tissues of which the pockets are composed, it may be stated that during the early stages of develop

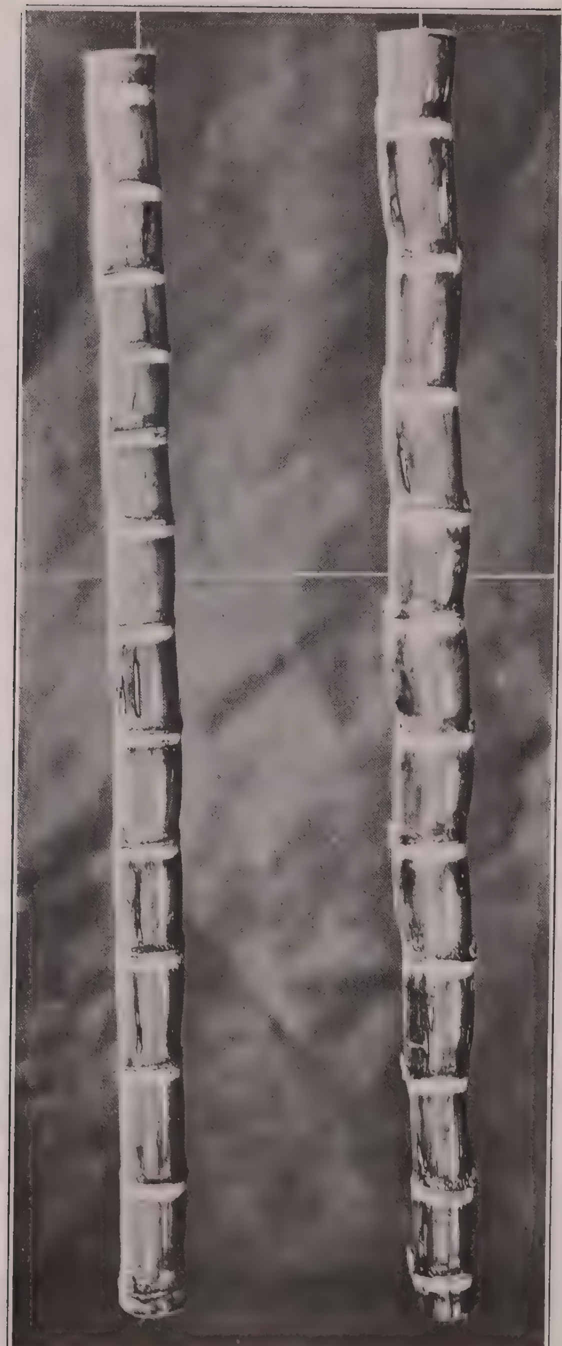

Figure 11—*Mosaic on Lahaina.* A portion of two diseased stalks showing cankers in the rind.

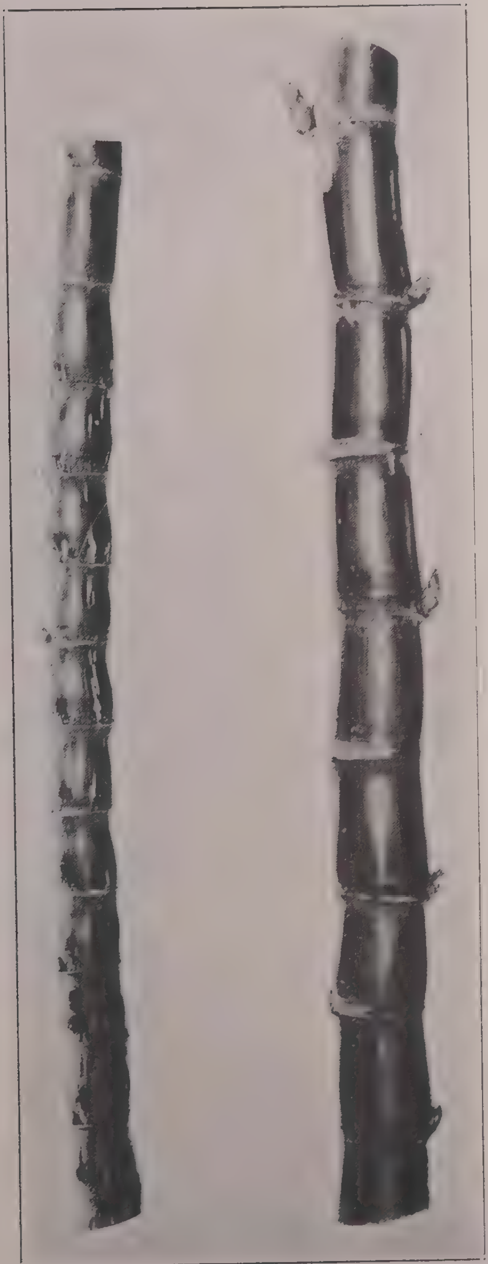

Figure 12—*Mosaic on Badila.* Portions of a healthy and a diseased stalk. The diseased stalk shows elongated dead areas in the rind.

ment, many of the cells contain intracellular bodies similar to those which have been found in the inner stalk tissues of mosaic corn plants.[4] At a very early stage in the development of the pockets, the cells containing the amoeboid bodies, as well as a considerable number of cells that do not contain them, die and collapse. At about the same time, the granular precipitate described by Matz appears in the tissues surrounding the disintegrating cells. As the internodes grow, the pockets of diseased tissue take on different shades of color. The color

Figure 13—*Mosaic on Hawaii* 109. Cross sections of one healthy and three diseased stalks. The diseased sections show the necrotic masses of tissue produced in the stalk.

varies from a light yellowish or reddish brown to dark brown. As the tissue in the diseased pockets disintegrates, cavities of different sizes are produced. The cavities are, in some instances, almost spherical, but more often elongated. Their sides are lined with discolored tissues, the cells of which contain a more or less granular deposit. The extent to which actual breaking down of tissues occurs in the diseased pockets varies greatly with different specimens and with different varieties. In some cases, very large cavities as much as one-half centimeter in diameter and several centimeters long are produced. In other instances, however, no cavity is produced and little or no breaking down of tissues occurs. In such

cases, the diseased pockets can be distinguished by discoloration and the presence of a granular deposit. The deposit may consist of very small granules or of rather large ones. The granules in the outer tissues of diseased pockets are often quite small, while those toward the center are larger. In young growing tissue, the deposit is a light yellowish color; in old tissue, it becomes brown. It is always associated with the internal lesions and the masses of brown colored tissue. Text figure 13 shows one section of healthy and three sections of diseased stalk tissue of the variety Hawaii 109. The discolored necrotic masses occuring on the surface of the cut tissue are plainly shown; those that lie beneath the surface appear as dark blotches of indefinite outline.

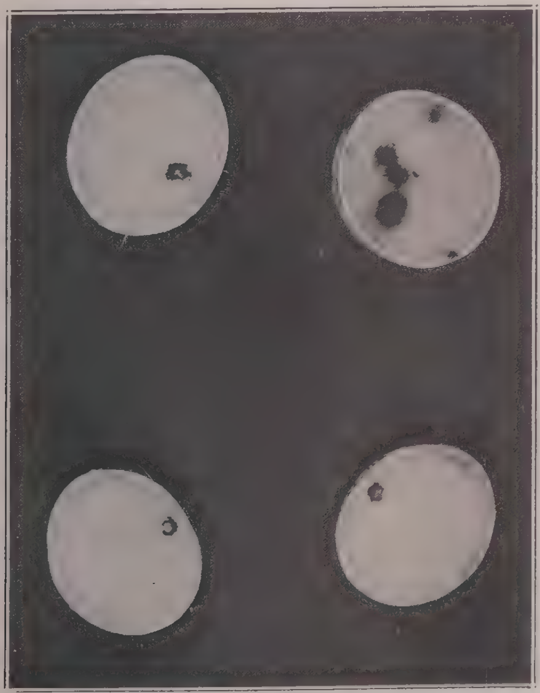

Figure 14—*Mosaic on Hawaii* 109. Sections through a mature stalk showing circular bands of necrotic tissue.

In some internodes, the pockets of diseased tissue are quite numerous, while in others only a few or none at all are present. They are usually separated by sound tissue, but in badly diseased stalks the entire inner tissue may be involved. In such cases, the whole tissue takes on a light yellow color. There is a tendency for the pockets to be grouped just beneath the rind. Many of them occur from two to five millimeters deep, but they may also occur in any part of the stalk tissue. They are larger and more numerous in the internodes than in the nodes.

In some stalks, the masses of diseased tissue containing the granular deposit have in their centers normally colored and apparently healthy tissue. When these

masses are cut into cross sections, the discolored tissue appears in the form of circles. Cross sections through a stalk of the variety Hawaii 109, showing the circles of necrotic tissue, are shown in text figure 14. It is believed that this form of necrosis in the stalk corresponds to the zonation shown by the chlorotic tissue in the light green-colored spots on certain diseased leaves.

Transmission of the Disease.

The fact that sugar cane mosaic is transmitted through diseased cuttings is now well established. Some workers have gone so far as to claim that diseased seed pieces invariably give rise to diseased stools. This statement, however, does not hold true under Hawaiian conditions. It has been observed that diseased cuttings from certain varieties frequently produce healthy stools. This is especially true for the varieties Striped Tip and Yellow Tip. It was shown by an experiment carried out in 1920 that seed from badly diseased cuttings of the variety Striped Tip may give healthy stools. On April 7, one hundred fifty cuttings were made from badly diseased stalks of Striped Tip cane. Only one seed piece was cut from the upper portion of each diseased stalk. On April 9, fifty of the cuttings were planted in one row, while the one hundred remaining cuttings were planted in a second row. Rather poor germination was obtained because of the inferior quality of the seed. The fifty seed pieces planted in the first row gave thirty-nine stools. Of these, fourteen were healthy and remained healthy up to the time the cane was five months old. On November 24, when the stools were observed for the last time, thirteen of them were still healthy. One stool which had been healthy up to the end of September showed mosaic in one shoot. The one hundred cuttings planted in the second row gave only forty-eight stools. Of these, fifteen were healthy and remained healthy up to November 24, when they were observed for the last time. The experiment shows that diseased cuttings of this variety gave a considerable number of healthy stools. For most varieties, however, the disease is quite regularly transmitted through cuttings.

In 1910 Brandes brought proof that the corn aphid, *Aphis maidis* Fitch, is capable of spreading sugar cane mosaic. This important discovery has been confirmed by the writer[8] and others. Up to the present time, no sugar cane insect is known to transmit the disease. There is good evidence that the insects commonly prevalent on cane in Hawaii do not spread mosaic. It is now believed that most, if not all, of the spread of mosaic in cane fields here can be attributed to the corn aphid. Experiments have shown this insect to be more active than was at first supposed. Young seedlings of Sudan grass, one of its favorite hosts, were grown in pots in insect proof cages, and, after reaching a height of approximately one foot, were exposed for different periods of time on a grass lawn about fifty yards from aphid-infested corn and Sudan grass plants. It was found that an exposure of one day was usually sufficient to bring about an infestation of most of the seedlings by the winged form of the corn aphid. While *Aphis maidis* does not flourish on the varieties of cane grown commercially in Hawaii and has never been observed to establish a colony on cane plants here, it can live on cane for a number of days and readily transmits mosaic disease. It flourishes on a number of different plants, some of which are also subject to the mosaic of sugar cane.

The corn aphid has thus far been observed to establish its colonies in Hawaii on the following plants: corn, sorghum, Sudan grass, wonder forage grass, Tunis grass, Johnson grass, Kaffir corn, goose grass, *Eleusine indica* (L.) Gaertn., bristly fox-tail grass, *Chaetochloa verticillata* (L.) Scribn., the bur grass, *Cenchrus echinatus* L., the crab grasses, *Syntherisma chinensis* (Ness), Hitch., and *S. debilis* (Desf.) Skeels, an unidentified species of *Echinochloa* and the club rush, *Scirpus maritimus* L.

Sugar cane mosaic may also be transmitted by mechanical means. The first adequate proof of this fact was given by Brandes in 1920. In well controlled experiments, he obtained infection by inoculating juice from diseased plants into healthy ones. The writer has been able to confirm this work in several different experiments, one of which is here described.

Healthy seed of the variety Striped Tip was obtained from Manoa Valley and planted in soy tubs kept in insect-proof cages. This seed gave only healthy plants. On December 8, 1921, when the plants were about two feet high, undiluted juice pressed from the leaves and upper joints of diseased Lahaina plants was rubbed into wounds made on the young leaves of six healthy Striped Tip plants. The leaves were wounded by crushing them between finger and thumb. The wounded tissue was inoculated by rubbing it with a small piece of absorbent cotton saturated with diseased juice. In the same way juice from healthy Lahaina plants was rubbed into the wounded leaves of five other healthy Striped Tip plants that served as checks. Since no infections were obtained, the inoculations were repeated on December 26, 1921, and on January 4, 1922. On April 7, when the experiment was ended, five of the six plants inoculated with juice from mosaic Lahaina plants had mosaic. One of the plants remained healthy. The five check plants, into the leaves of which juice from healthy Lahaina plants was rubbed, remained healthy. The experiment demonstrates the transmission of sugar cane mosaic by means of juice from mosaic plants.

Sugar Cane Mosaic on Other Grasses in Hawaii.

At least three wild grasses and several cultivated grasses grown in Hawaii are known to take mosaic disease. The wild grasses known to be subject to mosaic are: the bristly fox-tail grass, *Chaetochloa verticillata* (L.) Scribn., goose grass, *Eleusine indica* (L.) Gaertn, and the crab grass, *Syntherisma pruriens* (Trin.) Arthur. The cultivated grasses known to be subject to mosaic are: Sudan grass. *Andropogon sorghum sudanensis* Piper, wonder forage grass, *Andropogon sp.*, Tunis grass, *Andropogon sorghum virgatus* (Hack.) Piper, and Guatemala grass, *Tripsacum laxum,* Wash.

It has been shown that the mosaic on bristly fox-tail grass, Sudan grass and wonder forage grass is the same disease as that on sugar cane by transferring the mosaic on Sudan grass to sugar cane, bristly fox-tail grass and wonder forage grass.

On February 10, 1922, approximately fifty corn aphids were transferred from mosaic Sudan grass plants to each of four healthy cane plants of the variety Striped Tip growing in four different insect-proof cages. Four other caged plants

of the same age and variety were used as checks. On April 14, it was observed that three of the plants on which corn aphids were placed had taken mosaic. The fourth plant was still healthy and remained healthy up to April 28, when the ex-

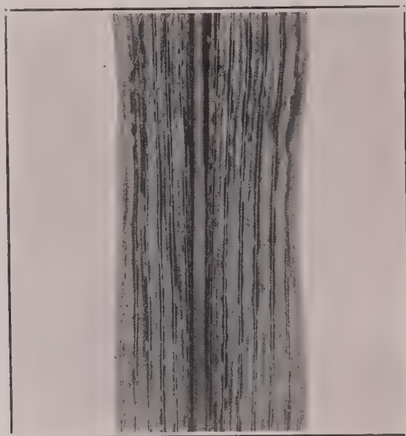

Figure 15—*Sugar cane Mosaic on Sudan grass.* A portion of a young leaf showing chlorotic spots and stripes.

periment was ended. The results of this experiment were confirmed by two similar ones carried out at a later date. A portion of a mosaic leaf of Sudan grass is shown in figure 15.

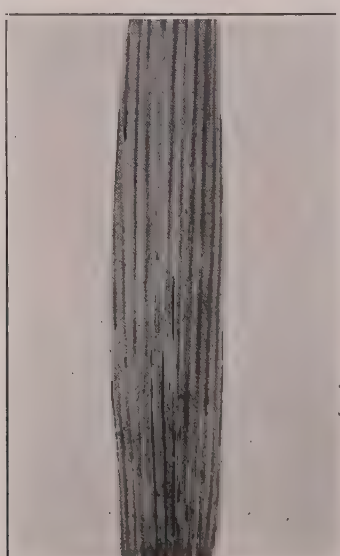

Figure 16—*Sugar cane Mosaic on bristly fox-tail grass.* A portion of a young leaf showing elongated green areas surrounded by chlorotic tissue.

On July 24, approximately fifty corn aphids were transferred from mosaic Sudan grass plants to each of four healthy young plants of bristly foxtail grass, which had been grown from seed and kept constantly in insect-proof cages. On July 29, approximately fifty more corn aphids from mosaic Sudan grass were placed on each of the same four bristly foxtail seedlings. Four other healthy, young, caged seedlings of the same age served as checks. On August 18, it was observed that two of the plants on which aphids had been placed showed mosaic. The other two aphid-infested plants and the four check plants were healthy and remained so up to September 1, when the experiment was ended. A portion of a mosaic leaf of the bristly foxtail grass is shown in figure 16.

On August 25, 1922, approximately fifty corn aphids from mosaic Sudan grass were transferred to four healthy, young, caged seedlings of wonder forage grass. Four other healthy, young, caged seedlings of the same age served as checks. On September 12, when the experiment was ended, all of the four plants on which aphids had been placed showed mosaic. The four check plants were still healthy. A portion of a mosaic leaf of wonder forage grass is shown in figure 17.

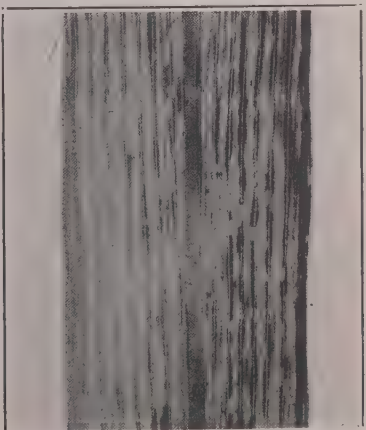

Figure 17—*Sugar cane Mosaic on Wonder forage grass.* A portion of a young leaf showing chlorotic spots and stripes.

No attempt has yet been made to transfer mosaic from sugar cane or from Sudan grass to goose grass, crab grass, Tunis grass or Guatemala grass. It is probable, however, that the mosaic on these grasses is the same as that on sugar cane. Figures 18 and 19 show portions of mosaic leaves of Tunis grass and Guatemala grass respectively. With the exception of Guatemala grass, all of the above mentioned grasses are known to serve as host plants for the corn aphid.

Effect of Sunlight on the Disease.

The fact that the mosaic pattern is most pronounced on young leaves, and that the old leaves of many diseased plants show a certain amount of recovery from

chlorosis, suggested the hypothesis that full sunlight may have a tendency to inhibit the action of the causal agent. In testing this hypothesis, some experiments on the effect of sunlight on very young leaves were undertaken. The varieties Lahaina and Striped Tip were used. Young leaves are normally more or less shaded by the older ones until they are almost mature. In order to expose these leaves to full sunlight during the greater part of their growing period, the tops were removed from a considerable number of growing diseased stalks. The tops were cut squarely off at a point one half to three centimeters above the terminal

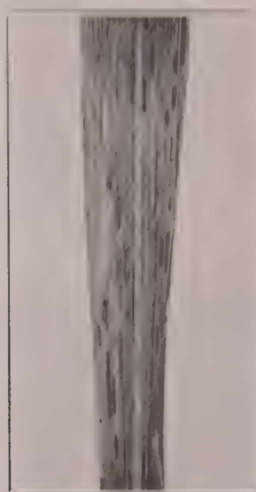

Figure 18. *Mosaic on Tunis grass.* A portion of a young leaf showing chlorotic areas.

buds. The old leaves and leaf sheaths were thus removed and the young leaves exposed during their growth and development. It was found that leaves so exposed did not become diseased. In this way, healthy leaves were produced at will on diseased stalks. As soon as a new top was grown and the young leaves were once more protected, the disease again appeared but did not affect the leaves or portions of leaves that were exposed during their development. As new tops were produced, the upper parts of certain young leaves were exposed, while their lower parts were protected. The upper parts of such leaves remained healthy while the spots characteristic of mosaic disease covered their lower parts. This experiment has been repeated on several different occasions but always with the same result. It is believed to indicate that full sunlight hinders the action of the causative agent.

Susceptibility of Diseased Leaves to the Red Rot Fungus

It has been observed that in fields of Striped Tip and Yellow Tip cane, mosaic is a predisponent cause of attacks by the red rot fungus *Colletotrichum falcatum* Went. This fungus does little damage in Hawaii, but occasionally produces

elongated spots on the midribs of mature or old leaves. When plants of the varieties mentioned have mosaic they are much more subject to such leaf attacks than are healthy plants of the same varieties growing under similar conditions. This interesting relationship between the two diseases was first observed in Striped Tip and Yellow Tip fields on Honokaa Plantation. In these fields, a careful search

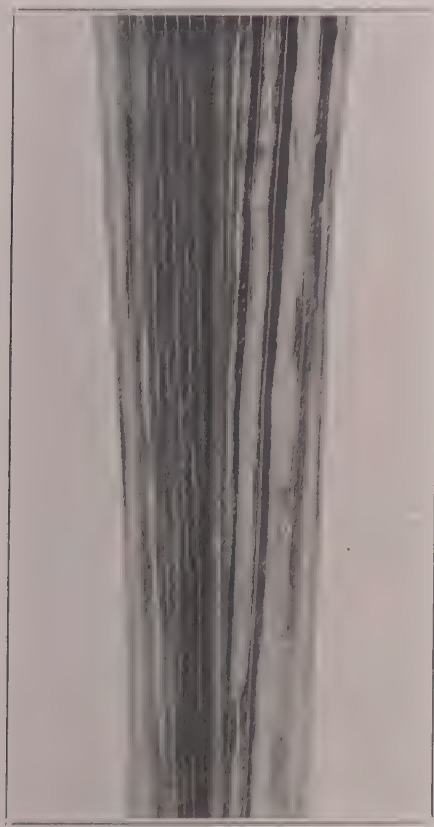

Figure 19—Mosaic on Guatemala grass. A portion of a young leaf showing chlorotic spots and stripes.

was necessary in order to find red-rot lesions on the leaves of plants free from mosaic. On the other hand, spots due to Colletrichum were present on the leaves of practically every plant having mosaic. Since many of the leaves of mosaic plants were broken at the points where they were attacked by the fungus, it was possible to recognize such plants before coming near enough to observe the symptoms of mosaic. The same association between the two diseases was also observed in plots of Striped Tip cane grown in the City of Honolulu and in an experiment on Honolulu Plantation. Mosaic apparently lowers the resistance of the Tip canes and predisposes them to attacks by the red-rot fungus.

Recovery from the Disease.

It was observed that diseased stools of certain varieties frequently recover. Careful studies show that this may come about in either of two different ways.

The diseased shoots of a stool may at times begin to produce healthy leaves. Later, the old diseased leaves die and fall off. Such stools may grow to maturity without showing any further signs of disease on the leaves. They show no evidence of having been diseased unless the joints from which the diseased leaves grew have markings characteristic of mosaic. These stools become healthy through the recovery of the terminal buds of their diseased shoots. But the disease may also be overcome in quite a different way. Although none of the diseased shoots actually recover, the new shoots produced may be healthy. The diseased shoots remain small and are overgrown by the healthy ones. After a time, they die and the stool may then remain healthy to maturity. In other instances, a stool may be diseased or partly diseased in the plant crop or in one of the ratoon crops, but after this crop is harvested, it may produce only healthy shoots. Such stools may remain healthy through the next and subsequent crop periods. This is the manner in which many stools were observed to recover in experiments made to test the effect of mosaic on yield. Some of these experiments are described in detail in another place, where many cases of such recoveries are recorded.

Several instances of recovery by the first of the above described methods were observed among seedlings grown in experimental plots on the grounds of the Experiment Station of the Hawaiian Sugar Planters' Association. On April 4, 1920, three hundred fifty-nine healthy seedlings of Lahaina parentage were transplanted from pots to field plots. They were planted about three feet apart in rows. By June 17, thirteen had taken mosaic. By July 22, eight more were diseased. By September 16, one more was diseased, making a total of twenty-two diseased stools. In most cases, only one or a few of the shoots in each stool were infected. During the year 1920, seven of these twenty-two stools recovered.

On July 17, it was observed that five of the diseased stools were on the way to recovery. In four of these, the new leaves produced by the diseased shoots were healthy. In the other stool, the new leaves on the diseased shoots showed only a few of the light colored spots so characteristic of mosaic. All of the shoots that had been diseased but were producing healthy leaves were tagged on September 16. The lower leaves on all of the shoots tagged plainly showed the disease on this date. After a time, the lower leaves died and fell off. There was then no way of knowing that they had ever been diseased except by reference to records and by the tags that marked them. Recovery seems to have been complete, for all of the seven recovered stools remained healthy up to the time they were harvested in May, 1922.

At the time of harvesting, the plants were destroyed after seed had been cut from all of the living shoots of each stool. The seven different lots of seed were planted in separate rows on May 12, 1922. One month after planting, all of the resulting stools were healthy, but by August 1, one plant in each of five of the rows had become diseased. All of the stools from seed of two of the originally infected stools remained healthy during the nine months that they were kept

under observation. It is believed that the seed from all of the seven stools was healthy and that the disease observed in five of the plants was due to new infections.

The ends of two of the shoots that had been observed to recover and were tagged were planted without destroying the terminal buds. From these buds, two new stools developed. Both remained healthy up to the time they were six months old. After a period of nine months, one stool was still healthy but, in the other stool, one shoot had become diseased. This was probably the result of a new infection. It is quite evident that the two shoots, from which these hills were grown, had completely recovered.

Effect of Mosaic on Commercial Varieties of Cane: Losses Caused by the Disease.

Plantation men in Hawaii are by no means agreed as to the extent of the losses due to mosaic. Some regard it as a very serious disease, while others are of the opinion that it does little damage. Similar differences of opinion have also been expressed by those who have studied the disease in other cane growing countries. Before deciding what control measures are justified, it is necessary to have a reasonably correct estimate of the losses suffered. For this reason, it has seemed desirable to make further studies on the injury due to mosaic.

It is generally recognized that different commercial varieties of cane react differently toward the disease. Some are very susceptible, while others are known to be more or less resistant. In certain varieties the disease causes severe stunting, while in others this symptom is hardly noticeable. In order to test the effect of the disease on different commercial varieties, four field experiments, covering approximately one-half acre each, were planted in 1920. They were located in four different districts as follows: Puunene, Maui (Field F of the Hawaiian Commercial & Sugar Company); Honokaa, Hawaii (Field 26 of the Honokaa Sugar Company); Pearl City, Oahu (Field 40 of the Honolulu Plantation Company); and Waialua, Oahu (Field 3 B of the Waialua Agricultural Company, Ltd.). The experiment at Puunene was planted July 30; that at Honokaa, August 5; that at Pearl City, September 16; and that at Waialua, November 10. Each experiment was intended to be a duplication of each of the others, but because of the difficulty in getting suitable seed of some varieties, certain changes in the original plans were made. The varieties Demerara 1135, Hawaii 109, and Lahaina were used in all of the four experiments. The varieties Demerara 117 and Yellow Caledonia were used in the experiments at Puunene, Honokaa and Waialua, but at Pearl City, Badila and Striped Tip were substituted for these varieties. The variety Yellow Tip was added to the list of those used in the experiments at Puunene and Honokaa.

The general plan was to plant one hundred twenty hills with healthy seed and one hundred twenty hills with diseased seed of each variety in each experiment. The healthy and diseased seed pieces were planted alternately in the lines, five healthy and five diseased cuttings beings placed in each thirty foot line. The first hill in each line was always planted with healthy seed, while the last one was always planted with diseased seed. The hills in each thirty-foot row or line

were numbered 1 to 10. Those hills bearing odd numbers were planted with healthy seed, while the ones bearing even numbers were planted with diseased seed. This method of planting gave considerable space between the stools and made it possible to determine from which cutting each shoot grew. The stools from healthy and diseased seed had an equal chance to grow and produce a crop.

As soon as the cane was well above ground, every stool was carefully observed and a record made as to whether or not it showed mosaic. The hills in which the original seed failed to germinate were replanted. Further records were made from time to time until the cane became so large that it was no longer possible to make accurate observations because of the size and the tangling of the stalks. All of the experiments were harvested in 1922. The plot at Pearl City was harvested May 10; that at Waialua June 3 to 7; that at Puunene July 7 to 8; and that at Honokaa August 10. When harvested, the cane at Waialua was about nineteen months old; that at Pearl City about twenty months old; and that at Puunene and at Honokaa about two years old. Each stool was weighed separately and a record made of the yield of cane resulting from each healthy and each diseased seed piece. As soon as the ratoons were well up, each stool was carefully observed and a record made as to whether or not it showed mosaic. In the case of mosaic stools, observations were made to determine whether they were wholly or only partly diseased. A record of the behaviour of each stool for a period of more than two years was thus obtained. This record shows the effect of mosaic on the yield of the different varieties planted. It also shows their resistance to infection and the ability of certain varieties to recover. This data is too extensive to publish in full or in detail, but an outline of the record for the experiments at Pearl City and at Waialua is given in Tables I to X.

In the tables, the rows or lines are numbered from 1 to 24 and the stools from 1 to 10. The first column under each stool number gives the date on which the stool was first observed and its condition as regards mosaic. A plus sign (+) indicates that the stool was healthy, a double plus sign (‡) that it was diseased, and a minus sign (—), that it was missing. The second column under each stool number gives the date on which the stool was observed for the last time before harvest and indicates, by the same signs as used in the first column, the condition of the stools on that date. The third column under each stool number gives the date on which the experiment was harvested and the yield from each stool. If the weight of cane from a stool was less than one-half pound, it was marked with a zero sign (0). The fourth column under each stool number gives the date on which the ratoons were first observed and the condition of each stool on that date. The number sign (#) indicates that the stool was wholly diseased, i.e., that every shoot was diseased; the times sign (×) that the stool was only partly diseased, i.e., that some shoots were healthy. The plus and minus signs have the same meaning as in columns one and two. Reading from Table I it will be seen that stool 1 (from healthy seed) in line 1 was healthy on November 12, 1920; that it was still healthy on April 28, 1921; that when harvested on May 10, 1922, it yielded thirty pounds of cane, and that the young ratoon was still healthy on September 6, 1922. It will also be seen that stool 2 (from diseased seed), line 1, was diseased on the first two dates; that it yielded less than one-half pound of cane when

harvested, and that the ratoon was wholly diseased on September 6, 1922. A similar record is given for each stool of each variety used in the two experiments. At the bottom of the columns under each stool number, in each table, is given the total yield of cane from all stools bearing that number. These totals show the effect of mosaic on each variety planted.

Tables I to V inclusive show the effect of mosaic on the different varieties of cane grown in the experiment at Pearl City. The effect of the disease on the variety Badila is shown in Table I. Of the hills planted with healthy seed, one was missing, one was diseased and one hundred eighteen were still healthy on April 28, 1921, when the cane was about seven months old. Of the hills from diseased seed, four were missing, eighteen were healthy and ninety-eight were diseased on this date. The stools from healthy seed yielded 5,466 pounds of cane, while the stools from the same quantity of diseased seed yielded only 1,196 pounds of cane. Of the hills from healthy seed, six were missing, two were partly diseased, one was wholly diseased and one hundred eleven were still healthy on September 6, 1922. Of the hills planted with diseased seed, thirty-four were missing, thirty were partly diseased, twenty-seven were wholly diseased, and twenty-nine were healthy on the same date. During the two years the plot was under observation, the disease spread to three healthy hills grown from healthy seed. Sixteen diseased hills from diseased seed recovered from the disease. Stool 7, in line 21, showed mosaic when first observed and probably came from a diseased cutting. Since the healthy and diseased seed was in most instances taken from the same fields, a few diseased cuttings may have accidentally been included among the healthy ones and vice versa.

The effect of mosaic on the variety Hawaii 109, grown in the experiment at Pearl City, is shown in Table II. Of the one hundred twenty hills planted with healthy seed, one was missing, one was diseased, and one hundred eighteen were healthy on April 28, when the stools were approximately seven months old. Of the one hundred twenty hills planted with diseased seed, seven were missing, fifteen were healthy and ninety-eight were diseased on this date. The stools from healthy seed yielded 5,235 pounds of cane; those from diseased seed yielded only 3,330 pounds of cane. Of the hills planted with healthy seed, one was missing, four were partly diseased, one was wholly diseased, and one hundred fourteen were still healthy on September 6, 1922. Of the hills planted with diseased seed, eleven were missing, thirty were partly diseased, fifty-four were wholly diseased and twenty-five were healthy on the same date. During the two years the experiment was under observation, five of the healthy hills from healthy seed became diseased, and eleven of the diseased hills from diseased seed recovered.

Table III shows the effect of mosaic on the variety Lahaina in the experiment at Pearl City. Of the hills planted with healthy seed, eleven were diseased and the remaining one hundred nine stools were still healthy when the cane was seven months old. Of the hills planted with diseased seed, two were missing and the remaining one hundred eighteen hills were diseased after seven months. The stools from healthy seed yielded 4,947 pounds of cane; the stools from diseased seed, only 1,382 pounds of cane. Of the hills planted with healthy seed, eight were missing, four were partly diseased, eleven were wholly diseased and

TABLE I

Stool	1				2				3				4				5			
Line	Nov. 12, 1920	Apr. 28, 1921	Yield May 10, 1922	Sept. 6, 1922	Nov. 12, 1920	Apr. 28, 1921	Yield May 10, 1922	Sept. 6, 1922	Nov. 12, 1920	Apr. 28, 1921	Yield May 10, 1922	Sept. 6, 1922	Nov. 12, 1920	Apr. 28, 1921	Yield May 10, 1922	Sept. 6, 1922	Nov 12, 1920	Apr. 28, 1921	Yield May 10, 1922	Sept 6, 1922
1	+	+	30	+	‡	‡	0	#	−	+	0	−	‡	‡	19	−	+	+	48	+
2	−	+	0	+	−	‡	7	−	+	+	62	+	‡	‡	1	−	+	+	53	+
3	+	+	11	+	‡	‡	7	+	+	+	50	+	‡	‡	3	#	−	+	4	#
4	+	+	52	+	‡	‡	1	−	+	+	66	+	‡	‡	7	#	+	+	22	−
5	+	+	30	+	−	‡	1	+	+	+	50	+	−	‡	1	#	+	+	79	+
6	+	+	56	+	‡	‡	3	#	+	+	52	+	‡	‡	4	#	+	+	31	−
7	+	+	40	+	‡	‡	0	−	+	+	79	+	+	+	10	+	+	+	39	+
8	−	+	25	+	‡	‡	2	−	+	+	41	+	‡	‡	9	X	−	+	19	+
9	+	+	38	+	+	−	0	−	+	+	19	+	‡	‡	1	#	+	+	37	+
10	+	+	60	+	‡	‡	2	#	+	+	54	+	−	‡	5	#	+	+	68	+
11	+	+	62	+	‡	‡	1	#	+	+	2	−	+	+	58	+	+	+	56	+
12	+	+	32	+	‡	‡	6	X	+	+	49	+	‡	‡	2	−	−	+	25	+
13	+	+	57	+	‡	‡	4	#	+	+	25	+	‡	‡	3	−	+	+	74	+
14	+	+	48	+	‡	‡	3	−	+	+	64	+	‡	‡	0	−	+	+	63	+
15	+	+	42	+	−	‡	1	#	+	+	88	+	‡	‡	1	−	+	+	51	+
16	−	+	29	+	+	+	44	+	−	−	29	X	‡	‡	55	+	+	+	33	X
17	+	+	16	+	−	‡	1	−	+	+	27	+	‡	‡	1	−	+	+	17	+
18	−	+	0	+	−	‡	46	−	+	+	41	+	‡	‡	1	−	+	+	48	+
19	+	+	0	+	+	+	37	X	+	+	13	+	‡	‡	17	#	+	+	33	+
20	−	+	11	+	+	+	1	−	+	+	11	+	‡	‡	3	−	+	+	30	+
21	−	+	5	+	‡	‡	7	#	+	+	55	+	‡	‡	1	−	+	+	24	+
22	−	+	13	+	‡	‡	10	X	+	+	60	+	−	‡	4	#	+	+	35	+
23	+	+	55	+	‡	‡	0	−	+	+	65	+	‡	‡	25	X	+	+	31	+
24	−	+	7	+	+	+	39	+	−	+	12	+	‡	‡	7	+	+	+	89	+
	Yield From Healthy Seed 719 lbs.				Yield From Diseased Seed 223 lbs.				Yield From Healthy Seed 1014 lbs.				Yield From Diseased Seed 238 lbs.				Yield From Healthy Seed. 1009 lbs.			

Reaction of the variety Badila to mosaic in the experiment at Pearl City.

TABLE I—Continued

Stool	6				7				8				9				10			
Line	Nov. 12, 1920	Apr. 28, 1921	Yield May 10, 1922	Sept. 6, 1922	Nov. 12, 1920	Apr. 28, 1921	Yield May 10, 1922	Sept. 6, 1922	Nov. 12, 1920	Apr. 28, 1921	Yield May 10, 1922	Sept. 6, 1922	Nov. 12, 1920	Apr. 28, 1921	Yield May 10, 1922	Sept. 6, 1922	Nov. 12, 1920	Apr. 28, 1921	Yield May 10, 1922	Sept. 6, 1922
1	‡	‡	4	+	+	+	37	+	+	+	18	+	+	+	37	+	‡	‡	9	#
2	‡	‡	1	–	+	+	54	+	+	+	10	+	+	+	40	+	‡	‡	7	×
3	‡	‡	3	×	+	+	68	+	‡	+	1	–	+	+	68	+	–	‡	1	–
4	‡	‡	20	×	+	+	40	+	+	‡	20	+	+	+	99	+	‡	‡	3	–
5	‡	‡	4	×	+	+	37	+	‡	‡	21	×	+	+	66	–	–	‡	2	+
6	‡	‡	6	#	+	+	52	+	‡	‡	32	+	+	+	66	+	–	‡	1	+
7	‡	‡	8	#	+	+	77	+	+	‡	7	×	+	+	97	+	+	+	9	+
8	+	‡	24	+	+	+	91	+	–	‡	0	–	+	+	82	+	–	‡	7	+
9	‡	‡	9	#	+	+	36	+	‡	‡	1	#	+	+	46	+	+	+	48	+
10	‡	‡	5	+	+	+	60	+	+	+	25	+	+	+	56	+	‡	‡	4	#
11	‡	‡	0	–	+	+	74	+	–	‡	0	–	+	+	33	+	–	–	2	#
12	‡	‡	8	#	+	+	95	+	+	‡	15	×	+	+	39	+	‡	‡	16	×
13	‡	‡	10	×	+	+	75	+	‡	‡	10	×	+	+	82	+	‡	‡	16	×
14	‡	‡	2	–	+	+	60	+	‡	‡	14	×	+	+	58	+	+	+	11	×
15	‡	‡	2	#	+	+	82	+	‡	‡	18	+	+	+	59	+	+	+	23	+
16	‡	‡	19	×	+	+	11	+	–	+	0	+	+	+	65	+	+	+	64	–
17	‡	‡	4	×	+	+	25	–	‡	‡	2	–	–	+	25	+	‡	‡	2	#
18	‡	‡	10	+	+	+	35	+	‡	‡	5	×	+	+	104	+	‡	‡	0	×
19	‡	‡	12	×	+	+	39	+	‡	‡	6	#	+	+	67	+	‡	‡	17	×
20	‡	‡	1	–	+	+	50	+	‡	‡	8	+	+	+	64	+	+	+	33	+
21	‡	‡	10	×	‡	‡	7	+	+	‡	12	×	+	+	62	+	–	–	7	#
22	‡	‡	7	×	+	+	33	+	‡	‡	3	–	–	+	5	+	–	–	0	–
23	+	+	17	+	+	+	77	+	‡	‡	15	+	+	+	41	+	‡	‡	5	×
24	‡	‡	3	×	+	+	93	+	‡	‡	1	–	+	+	55	+	‡	‡	15	×
	Yield From Diseased Seed 189 lbs.				Yield From Healthy Seed 1308 lbs.				Yield From Diseased Seed 244 lbs.				Yield From Healthy Seed 1416 lbs				Yield From Diseased Seed 302 lbs.			

The plus sign (+) indicates a healthy stool; the double plus sign (‡), a diseased stool; the times sign (×), a partly diseased stool; the number sign (#), a wholly diseased stool; and the minus sign (—), a missing stool.

TABLE II

Stool	1				2				3				4				5			
Line	Nov. 12,1920	Apr. 28,1921	Yield May 10,1922	Sept. 6,1922	Nov. 12,1920	Apr. 28,1921	Yield May 10,1922	Sept. 6,1922	Nov. 12,1920	Apr. 28,1921	Yield May 10,1922	Sept. 6,1922	Nov. 12,1920	Apr. 28,1921	Yield May 10,1922	Sept. 6,1922	Nov. 12,1920	Apr. 28,1921	Yield May 10,1922	Sept. 6,1922
1	−	+	11	+	‡	‡	46	#	+	+	91	+	‡	‡	18	#	+	+	48	+
2	+	+	23	+	‡	‡	28	#	+	+	53	+	‡	‡	42	#	+	+	52	+
3	−	+	12	+	‡	‡	48	×	−	+	9	+	‡	‡	48	#	+	‡	57	×
4	+	+	57	+	+	‡	10	#	−	+	34	+	‡	‡	23	#	+	+	99	+
5	+	+	26	+	+	+	13	+	+	+	45	+	‡	‡	14	+	+	+	44	+
6	+	+	47	+	−	+	11	+	+	+	63	+	+	+	42	+	+	+	50	+
7	+	+	71	+	−	‡	10	#	+	+	66	+	‡	‡	34	×	+	+	36	+
8	−	+	41	+	+	‡	59	#	−	+	6	+	−	−	27	#	−	+	49	+
9	+	+	33	+	−	‡	2	−	+	+	24	+	−	‡	2	+	+	+	48	#
10	+	+	0	+	+	−	10	−	+	+	65	+	+	−	21	−	+	+	47	+
11	−	+	32	+	−	−	28	+	+	+	71	+	‡	‡	30	#	+	+	55	+
12	−	+	31	+	−	‡	16	×	−	+	9	+	−	‡	20	#	−	+	36	+
13	−	+	12	+	‡	‡	50	×	−	+	16	+	‡	‡	14	×	+	+	27	+
14	+	+	87	+	‡	‡	16	#	−	+	35	+	‡	‡	42	×	+	+	78	+
15	+	+	79	+	+	+	60	+	+	+	87	+	‡	‡	23	#	+	+	82	+
16	−	+	30	+	+	‡	39	#	−	+	20	+	+	‡	15	#	−	+	115	+
17	+	+	41	+	+	‡	5	#	+	+	20	+	‡	‡	17	#	+	+	44	+
18	−	+	23	+	‡	‡	15	×	+	+	25	+	‡	‡	43	×	+	+	52	+
19	+	+	52	+	−	‡	5	#	+	+	85	+	‡	‡	40	#	−	+	18	+
20	−	+	15	+	‡	‡	47	×	+	+	73	+	‡	‡	51	#	+	+	72	+
21	+	+	22	+	‡	‡	35	+	+	+	19	−	‡	‡	21	×	+	+	28	+
22	+	+	20	+	‡	‡	35	#	+	+	50	+	+	‡	17	×	−	+	4	+
23	+	+	98	+	−	‡	5	#	−	+	11	+	−	‡	73	−	+	+	10	+
24	−	+	15	+	−	‡	3	+	−	+	17	+	‡	‡	33	#	−	+	5	+
	Yield From Healthy Seed 878 lbs.				Yield From Diseased Seed 596 lbs.				Yield From Healthy Seed 994 lbs.				Yield From Diseased Seed 710 lbs.				Yield From Healthy Seed 1156 lbs.			

Reaction of the variety Hawaii 109 to mosaic in the experiment at Pearl City.

TABLE II—Continued

Stool	6				7				8				9				10			
Line	Nov. 12,1920	Apr. 28,1921	Yield May 10,1922	Sept. 6,1922	Nov. 12,1920	Apr. 28,1921	Yield May 10,1922	Sept. 6,1922	Nov. 12,1920	Apr. 28,1921	Yield May 10,1922	Sept. 6,1922	Nov. 12,1920	Apr. 28,1921	Yield May 10,1922	Sept. 6,1922	Nov. 12,1920	Apr. 28,1921	Yield May 10,1922	Sept. 6,1922
1	‡	‡	29	#	+	+	33	+	‡	‡	25	#	+	+	67	+	+	+	15	+
2	‡	‡	13	#	+	+	58	+	+	+	41	#	+	+	46	+	–	+	30	+
3	‡	‡	25	#	+	+	46	+	‡	‡	89	×	+	+	57	+	–	+	36	+
4	–	‡	10	#	+	+	29	+	‡	‡	11	+	+	+	39	+	‡	‡	44	#
5	–	–	0	–	–	–	0	+	‡	‡	52	+	+	+	51	+	‡	‡	29	×
6	‡	‡	55	#	+	+	14	+	+	‡	12	–	+	+	35	+	‡	‡	46	+
7	+	+	15	+	–	+	16	+	+	+	41	+	–	+	15	+	–	‡	21	#
8	‡	‡	10	#	–	+	0	+	‡	‡	64	#	+	+	53	+	–	‡	4	#
9	‡	‡	26	+	+	+	52	×	‡	‡	15	+	+	+	62	×	‡	‡	28	×
10	‡	‡	45	#	+	+	33	+	‡	‡	28	×	+	+	12	+	–	‡	0	#
11	‡	‡	0	×	+	+	3	+	‡	‡	23	×	+	+	104	+	–	+	10	+
12	+	‡	27	#	+	+	12	+	–	‡	45	–	+	+	87	+	–	–	0	–
13	‡	‡	46	×	+	+	31	+	–	–	75	–	+	+	53	+	–	‡	3	#
14	‡	‡	54	×	+	+	50	+	‡	‡	20	#	+	+	113	+	–	‡	3	×
15	‡	‡	50	#	+	+	53	+	‡	‡	55	#	+	+	109	×	–	‡	7	+
16	–	‡	11	×	–	+	15	+	+	‡	40	×	+	+	69	+	‡	+	35	+
17	+	+	37	+	–	+	10	+	–	‡	2	–	–	+	15	+	‡	‡	42	×
18	–	‡	10	#	+	+	60	+	‡	‡	33	#	+	+	60	+	‡	‡	8	#
19	‡	‡	50	#	–	+	35	+	‡	‡	17	#	+	+	55	+	–	‡	35	×
20	‡	‡	50	×	+	+	115	+	–	‡	10	×	+	+	55	+	‡	‡	35	×
21	‡	‡	11	#	–	+	10	+	‡	‡	20	#	+	+	55	+	‡	‡	45	#
22	–	+	5	+	+	+	74	+	‡	‡	45	×	+	+	69	+	–	‡	0	–
23	‡	‡	61	#	–	+	15	+	+	+	18	+	+	+	104	+	‡	‡	65	×
24	–	‡	9	#	–	+	18	+	–	‡	2	#	+	+	40	+	‡	‡	51	×
	Yield From Diseased Seed 649 lbs.				Yield From Healthy Seed 782 lbs.				Yield From Diseased Seed 783 lbs.				Yield From Healthy Seed 1425 lbs.				Yield From Diseased Seed 592 lbs			

The plus sign (+) indicates a healthy stool; the double plus sign (‡), a diseased stool; the times sign (×), a partly diseased stool; the number sign (#), a wholly diseased stool; and the minus sign (—), a missing stool.

TABLE III

Stool	1				2				3				4				5			
Line	Nov. 12,1920	Apr. 28,1921	Yield May 10,1922	Sept. 6,1922	Nov. 12,1920	Apr. 28,1921	Yield May 10,1922	Sept. 6,1922	Nov. 12,1920	Apr. 28,1921	Yield May 10,1922	Sept. 6,1922	Nov. 12,1920	Apr. 28,1921	Yield May 10,1922	Sept. 6,1922	Nov. 12,1920	Apr. 28,1921	Yield May 10,1922	Sept. 6,1922
1	–	+	1	+	‡	‡	17	#	+	+	48	+	+	‡	3	#	+	+	62	+
2	+	+	42	+	‡	‡	1	–	+	+	19	–	‡	‡	3	#	+	+	4	–
3	+	+	0	×	‡	‡	0	–	+	+	49	+	‡	‡	0	–	+	‡	49	#
4	+	+	35	+	–	‡	15	#	+	+	39	–	‡	‡	11	–	+	+	49	+
5	+	+	41	+	‡	‡	7	#	+	+	23	+	–	‡	5	–	+	+	36	+
6	+	‡	20	#	‡	‡	9	–	+	‡	55	×	‡	‡	11	#	+	+	29	#
7	–	‡	9	–	‡	‡	8	#	+	+	64	+	‡	‡	16	#	+	+	36	+
8	–	+	27	+	‡	‡	14	–	+	+	73	+	‡	‡	7	–	+	+	78	+
9	–	+	0	+	‡	‡	14	#	+	+	43	+	‡	‡	9	#	+	+	53	+
10	–	+	24	+	‡	‡	17	#	+	+	18	+	‡	‡	19	#	+	+	56	+
11	+	+	25	+	‡	‡	17	#	+	+	55	+	‡	‡	0	–	+	+	50	+
12	–	+	0	+	–	‡	12	–	–	+	36	+	‡	‡	8	–	+	+	57	+
13	–	+	8	+	‡	‡	7	#	+	+	41	+	‡	‡	21	–	+	+	34	+
14	–	+	28	+	‡	‡	41	#	+	+	42	#	‡	‡	25	–	+	‡	63	#
15	+	+	25	+	‡	‡	18	#	+	+	63	+	‡	‡	7	–	+	+	22	+
16	+	+	35	+	‡	‡	0	–	+	+	79	+	‡	‡	6	–	+	+	36	+
17	+	+	18	+	‡	‡	5	–	+	+	57	+	‡	‡	3	–	+	+	42	+
18	+	+	60	×	‡	‡	24	–	+	+	64	+	‡	‡	3	–	+	+	54	+
19	+	+	21	+	‡	‡	8	#	–	+	10	+	‡	‡	6	–	+	+	78	+
20	+	+	64	+	‡	–	11	–	+	+	12	+	‡	‡	0	#	+	‡	50	+
21	+	+	53	+	‡	‡	2	#	+	+	34	+	‡	‡	19	–	+	+	43	+
22	+	+	57	+	‡	‡	13	#	+	‡	27	#	‡	‡	16	–	+	+	20	+
23	+	+	43	+	‡	‡	6	–	+	+	17	+	–	‡	4	#	+	+	22	#
24	+	+	35	+	–	‡	0	–	+	+	57	+	–	‡	0	–	+	+	37	+
	Yield From Healthy Seed 671 lbs.				Yield From Diseased Seed 266 lbs.				Yield From Healthy Seed 1025 lbs.				Yield From Diseased Seed 202 lbs.				Yield From Healthy Seed 1060 lbs.			

Reaction of the variety Lahaina to mosaic in the experiment at Pearl City.

TABLE III—Continued

Stool	6				7				8				9				10			
Line	Nov. 12,1920	Apr. 28,1921	Yield May 10,1922	Sept 6,1922	Nov. 12,1920	Apr. 28,1921	Yield May 10,1922	Sept 6,1922	Nov. 12,1920	Apr. 28,1921	Yield May 10,1922	Sept. 6,1922	Nov. 12,1920	Apr. 28,1921	Yield May 10,1922	Sept. 6,1922	Nov. 12,1920	Apr. 28,1921	Yield May 10,1922	Sept. 6,1922
1	‡	‡	6	#	+	+	17	+	−	‡	3	−	+	+	45	+	‡	‡	14	#
2	‡	‡	5	#	+	+	11	+	‡	‡	1	−	+	+	66	+	−	‡	0	−
3	‡	‡	24	−	+	+	34	+	+	‡	16	−	+	+	23	+	+	‡	15	#
4	‡	‡	11	−	+	+	56	+	‡	‡	12	#	+	+	51	+	−	−	0	−
5	‡	‡	21	#	+	‡	56	#	‡	‡	13	#	+	+	74	+	‡	‡	16	#
6	‡	‡	13	#	+	+	14	#	‡	‡	15	#	+	+	37	#	‡	‡	24	−
7	‡	‡	19	#	+	+	27	+	‡	‡	8	−	+	+	34	+	‡	‡	20	#
8	‡	‡	5	−	+	+	43	+	‡	‡	7	−	+	+	55	+	‡	‡	14	#
9	‡	‡	6	−	+	+	47	+	‡	‡	3	#	+	+	67	+	‡	‡	27	#
10	‡	‡	35	−	+	+	80	+	−	‡	1	−	+	+	51	+	‡	‡	29	#
11	‡	‡	15	−	+	+	53	+	‡	‡	17	#	+	+	60	+	‡	‡	0	#
12	‡	‡	20	#	+	+	55	+	‡	‡	15	#	+	+	88	+	‡	‡	8	−
13	‡	‡	9	−	+	+	61	+	‡	‡	32	#	+	+	50	+	‡	‡	12	−
14	‡	‡	11	#	+	+	41	+	‡	‡	26	#	+	+	57	#	−	‡	2	−
15	‡	‡	24	#	+	+	43	+	‡	‡	22	#	+	+	54	+	‡	‡	27	#
16	‡	‡	23	−	+	+	45	+	‡	‡	11	−	+	+	30	+	‡	‡	9	#
17	‡	‡	7	−	+	+	25	−	‡	‡	16	#	+	+	74	+	−	‡	0	−
18	‡	‡	13	−	+	‡	40	−	‡	‡	29	#	+	+	32	+	−	‡	7	−
19	‡	‡	7	×	+	+	25	+	‡	‡	13	×	+	+	55	+	‡	‡	27	×
20	‡	‡	12	#	+	‡	22	+	‡	‡	22	#	+	+	39	+	‡	‡	7	−
21	−	‡	0	−	+	‡	52	−	‡	‡	7	#	+	+	67	−	‡	‡	7	−
22	‡	‡	17	#	−	+	2	+	‡	‡	5	−	+	+	56	+	‡	‡	0	−
23	‡	‡	7	−	+	+	59	+	‡	‡	4	−	+	+	38	+	‡	‡	17	#
24	‡	‡	3	#	+	+	52	+	‡	‡	14	−	+	+	28	×	‡	‡	7	#
	Yield From Diseased Seed 313 lbs.				Yield From Healthy Seed 960 lbs.				Yield From Diseased Seed 312 lbs.				Yield From Healthy Seed 1231 lbs.				Yield From Diseased Seed 289 lbs.			

The plus sign (+) indicates a healthy stool; the double plus sign (‡), a diseased stool; the times sign (×), a partly diseased stool; the number sign (#), a wholly diseased stool; and the minus sign (—), a missing stool.

TABLE IV

Stool	1				2				3				4				5			
Line	Nov. 12, 1920	Apr. 28, 1921	Yield May 10, 1922	Sept. 6, 1922	Nov. 12, 1920	Apr. 28, 1921	Yield May 10, 1922	Sept. 6, 1922	Nov. 12, 1920	Apr. 28, 1921	Yield May 10, 1922	Sept. 6, 1922	Nov. 12, 1920	Apr. 28, 1921	Yield May 10, 1922	Sept. 6, 1922	Nov. 12, 1920	Apr. 28, 1921	Yield May 10, 1922	Sept 6, 1922
1	−	+	2	+	‡	‡	7	+	+	+	31	+	‡	‡	18	×	+	+	1	−
2	+	+	65	+	‡	‡	11	+	+	−	0	−	‡	‡	57	×	+	+	28	+
3	+	+	56	+	‡	‡	3	+	+	+	43	+	−	‡	6	+	+	+	67	+
4	−	+	18	+	‡	‡	12	+	+	+	1	+	−	‡	3	×	−	−	47	−
5	+	+	75	+	‡	‡	28	×	+	+	43	+	‡	‡	27	×	+	+	50	+
6	+	+	47	+	‡	‡	26	×	−	+	10	+	‡	‡	43	×	+	+	64	+
7	+	+	72	+	‡	‡	7	×	+	+	47	+	‡	‡	32	+	+	+	37	+
8	+	+	48	+	‡	‡	30	+	+	+	66	+	−	‡	3	×	+	+	112	+
9	−	+	8	+	+	+	29	+	+	+	35	+	‡	‡	11	*	+	+	62	+
10	−	+	2	+	‡	‡	49	×	+	+	57	+	‡	‡	34	×	−	+	8	+
11	+	+	54	+	‡	‡	3	+	+	+	45	+	−	‡	3	+	+	+	107	+
12	−	+	14	+	‡	‡	34	+	−	+	0	+	+	+	6	+	+	+	49	+
13	−	+	5	+	+	+	61	+	+	+	56	+	‡	‡	19	+	+	+	67	+
14	−	+	4	+	‡	‡	23	×	+	+	88	+	‡	‡	19	+	+	+	39	+
15	+	+	69	+	−	‡	3	+	+	+	44	+	‡	‡	14	×	−	+	4	+
16	−	+	11	+	+	+	75	+	+	+	11	+	+	‡	25	×	+	+	49	+
17	+	+	46	+	‡	‡	15	+	+	+	40	+	‡	‡	53	+	+	+	66	+
18	+	+	47	+	‡	‡	33	+	+	+	4	+	‡	‡	49	+	+	+	46	+
19	+	+	88	+	−	‡	0	+	−	+	0	+	‡	‡	24	×	+	+	39	+
20	−	+	0	+	−	‡	23	+	−	+	3	×	‡	‡	22	+	+	+	69	+
21	+	+	59	+	‡	‡	15	×	+	+	38	+	‡	‡	11	×	+	+	23	+
22	−	+	15	+	‡	‡	35	×	+	+	47	+	−	‡	7	×	+	+	31	+
23	+	+	77	+	‡	‡	38	×	+	+	109	+	‡	‡	13	×	+	+	63	+
24	−	+	22	+	‡	‡	45	+	−	+	22	+	‡	‡	51	×	−	+	1	+
	Yield From Healthy Seed 904 lbs.				Yield From Diseased Seed 605 lbs.				Yield From Healthy Seed 840 lbs.				Yield From Diseased Seed 550 lbs.				Yield From Healthy Seed 1129 lbs.			

Reaction of the variety Demerara 1135 to mosaic in the experiment at Pearl City.

TABLE IV—Continued

Stool	6				7				8				9				10			
Line	Nov. 12, 1920	Apr. 28, 1921	Yield May 10, 1922	Sept. 6, 1922	Nov. 12, 1920	Apr. 28, 1921	Yield May 10, 1922	Sept. 6, 1922	Nov. 12, 1920	Apr. 28, 1921	Yield May 10, 1922	Sept. 6, 1922	Nov. 12, 1920	Apr. 28, 1921	Yield May 10, 1922	Sept. 6, 1922	Nov. 12, 1920	Apr. 28, 1921	Yield May 10, 1922	Sept. 6, 1922
1	‡	‡	6	+	+	+	54	+	‡	‡	17	+	+	+	93	+	‡	‡	21	×
2	‡	‡	25	×	+	+	29	+	‡	‡	24	+	+	+	56	×	+	+	33	+
3	+	+	22	+	+	+	30	+	‡	‡	30	+	+	+	78	+	‡	‡	54	×
4	‡	‡	24	×	+	+	0	+	‡	‡	15	+	+	+	45	+	‡	‡	42	+
5	–	‡	4	×	+	+	70	+	‡	‡	51	+	+	+	57	+	‡	‡	37	×
6	‡	‡	24	×	+	+	36	+	+	+	37	+	+	+	55	+	–	‡	5	×
7	‡	‡	13	+	+	+	39	+	‡	‡	21	+	+	+	83	+	–	‡	15	×
8	–	+	11	+	+	+	39	+	–	‡	8	+	+	+	36	+	‡	‡	59	×
9	‡	‡	38	×	+	+	55	+	‡	‡	4	+	–	+	16	+	+	+	78	+
10	‡	‡	48	×	+	+	22	+	+	+	41	+	+	+	23	+	–	‡	11	×
11	+	‡	26	×	+	+	53	+	+	‡	27	×	+	+	71	+	–	‡	6	#
12	‡	‡	54	×	+	+	34	+	–	+	74	+	–	+	6	+	‡	‡	53	×
13	‡	‡	40	+	+	+	57	+	‡	‡	30	+	+	+	68	+	‡	‡	45	×
14	‡	‡	23	+	+	+	89	+	+	+	88	+	+	+	48	+	–	‡	0	–
15	‡	‡	5	+	+	+	63	+	‡	‡	16	+	+	+	61	+	+	+	27	+
16	‡	‡	17	×	+	+	50	+	+	+	61	+	+	+	77	+	–	–	0	–
17	–	+	7	+	–	‡	5	+	+	+	48	+	+	+	77	+	‡	‡	37	+
18	‡	‡	16	+	+	+	45	+	+	+	39	+	+	+	70	+	–	‡	19	+
19	+	‡	29	–	+	+	44	+	‡	‡	43	×	+	+	67	+	‡	‡	16	×
20	‡	‡	24	+	–	+	18	+	–	+	4	+	+	+	77	+	–	+	26	+
21	+	‡	10	+	+	+	63	+	‡	‡	47	+	+	+	33	+	‡	‡	12	+
22	+	+	35	+	+	+	43	+	+	‡	5	+	+	+	69	+	–	+	6	+
23	‡	‡	43	×	+	+	75	+	‡	‡	29	×	+	+	94	+	–	‡	1	+
24	‡	‡	20	+	+	+	65	+	+	‡	45	+	+	+	33	+	–	‡	4	+
	Yield From Diseased Seed 564 lbs.				Yield From Healthy Seed 1078 lbs.				Yield From Diseased Seed 804 lbs.				Yield From Healthy Seed 1393 lbs.				Yield From Diseased Seed 607 lbs.			

The plus sign (+) indicates a healthy stool; the double plus sign (‡), a diseased stool; the times sign (×), a partly diseased stool; the number sign (#), a wholly diseased stool; and the minus sign (–), a missing stool.

TABLE V

Stool	1				2				3				4				5			
Line	Nov. 12,1920	Apr. 28,1921	Yield May 10,1922	Sept. 6,1922	Nov. 12,1920	Apr. 28,1921	Yield May 10,1922	Sept. 6,1922	Nov. 12,1920	Apr. 28,1921	Yield May 10,1922	Sept. 6,1922	Nov. 12,1920	Apr. 28,1921	Yield May 10,1922	Sept. 6,1922	Nov. 12,1920	Apr. 28,1921	Yield May 10,1922	Sept. 6,1922
1	+	+	13	×	‡	‡	2	−	+	‡	2	×	+	+	33	+	+	+	68	×
2	+	+	74	+	+	‡	2	+	+	+	112	+	‡	‡	0	−	+	+	109	+
3	+	+	109	+	‡	‡	9	×	+	+	169	+	‡	‡	1	×	‡	‡	1	×
4	+	‡	*	+	‡	‡	*	+	+	+	*	+	+	‡	*	×	+	‡	*	×
5	+	+	55	+	‡	‡	3	×	+	+	44	×	‡	‡	1	×	+	+	54	+
6	+	+	26	+	‡	‡	1	×	‡	‡	4	+	−	−	0	−	+	‡	46	×
7	−	‡	11	×	‡	‡	2	×	‡	‡	1	×	‡	‡	7	×	+	‡	26	×
8	−	−	18	−	‡	‡	7	×	+	+	73	−	‡	‡	0	×	+	+	102	−
9	−	−	0	×	‡	‡	2	+	+	+	59	−	‡	‡	0	+	‡	‡	7	×
10	+	+	6	+	‡	‡	0	−	+	+	49	×	−	‡	0	−	+	+	17	+
11	+	+	83	×	‡	‡	2	×	‡	‡	0	−	‡	‡	0	−	+	+	91	×
12	−	+	0	×	+	‡	57	+	‡	‡	1	×	‡	‡	2	×	‡	‡	17	+
13	+	+	39	+	‡	‡	61	−	+	+	51	+	‡	‡	3	+	+	+	54	+
14	−	−	0	×	‡	‡	8	×	+	+	76	×	‡	‡	39	+	+	+	3	×
15	−	+	23	+	‡	‡	1	×	+	+	91	×	‡	‡	2	×	+	‡	55	×
16	−	‡	5	×	‡	‡	4	×	+	+	101	#	‡	‡	55	×	+	‡	1	×
17	+	+	21	×	‡	‡	0	−	+	+	41	×	+	+	3	+	+	+	41	×
18	−	+	2	+	‡	‡	14	×	+	+	36	×	‡	‡	1	#	+	‡	28	×
19	−	−	0	−	‡	‡	5	×	+	+	19	×	‡	‡	2	#	+	+	81	×
20	+	‡	39	×	‡	‡	1	−	+	+	55	×	‡	‡	16	×	+	‡	59	×
21	+	+	59	+	‡	‡	0	−	+	+	57	×	‡	‡	2	×	+	+	47	+
22	‡	‡	21	+	‡	‡	2	+	+	+	45	+	‡	‡	6	+	‡	‡	62	+
23	+	+	121	+	+	‡	1	×	+	+	102	+	‡	‡	6	×	+	+	63	×
24	−	+	11	×	‡	‡	19	×	+	+	57	×	‡	‡	32	×	+	‡	6	×
	Yield From Healthy Seed 736 lbs.				Yield From Diseased Seed 203 lbs.				Yield From Healthy Seed 1245 lbs.				Yield From Diseased Seed 211 lbs.				Yield From Healthy Seed 1038 lbs.			

Reaction of the variety Striped Tip to mosaic in the experiment at Pearl City.
* Because of a misunderstanding, the cane from each stool in line 4 was not weighed separately.

TABLE V—Continued

Stool	6				7				8				9				10			
Line	Nov. 12, 1920	Apr. 28, 1921	Yield May 10, 1922	Sept. 6, 1922	Nov. 12, 1920	Apr. 28, 1921	Yield May 10, 1922	Sept. 6, 1922	Nov. 12, 1920	Apr. 28, 1921	Yield May 10, 1922	Sept. 6, 1922	Nov. 12, 1920	Apr. 28, 1921	Yield May 10, 1922	Sept. 6, 1922	Nov. 12, 1920	Apr. 28, 1921	Yield May 10, 1922	Sept. 6, 1922
1	‡	‡	7	×	‡	‡	3	×	−	‡	3	#	+	+	30	×	‡	‡	12	×
2	‡	‡	0	−	+	+	58	+	‡	‡	0	−	+	‡	39	×	‡	‡	0	−
3	‡	‡	9	×	+	‡	32	#	‡	‡	57	×	+	+	82	+	‡	‡	0	−
4	‡	‡	*	×	+	+	*	×	‡	‡	*	−	+	+	*	+	+	‡	*	×
5	‡	‡	1	×	+	+	43	×	‡	‡	4	×	+	+	49	+	‡	‡	1	×
6	‡	‡	8	×	+	‡	26	×	‡	‡	3	−	+	+	48	+	+	‡	31	+
7	+	‡	1	×	+	+	54	×	‡	‡	44	+	+	+	172	+	‡	‡	2	−
8	‡	‡	11	×	‡	‡	0	×	‡	‡	0	−	+	+	51	×	−	‡	0	−
9	‡	‡	1	×	+	‡	9	×	‡	‡	1	×	+	+	80	×	+	‡	1	×
10	‡	‡	5	×	+	+	16	+	‡	‡	3	×	+	+	2	+	‡	‡	5	+
11	‡	‡	6	×	‡	‡	3	#	‡	‡	4	×	‡	‡	0	−	‡	‡	16	×
12	‡	‡	1	×	+	+	112	−	−	‡	0	−	−	+	31	+	‡	‡	9	×
13	‡	‡	5	×	+	+	57	+	‡	‡	9	×	+	+	0	+	+	‡	76	+
14	+	‡	83	+	+	+	0	−	‡	‡	1	+	+	+	92	+	−	‡	0	+
15	‡	‡	0	+	+	+	119	+	‡	‡	2	#	+	+	104	+	‡	‡	12	×
16	‡	‡	0	#	‡	‡	0	×	‡	‡	9	×	−	‡	23	×	−	−	1	×
17	‡	‡	3	×	+	+	27	×	‡	‡	4	+	+	+	68	+	−	−	0	−
18	‡	‡	2	#	+	+	23	×	‡	‡	4	×	+	+	46	×	‡	‡	1	×
19	‡	‡	0	−	+	+	119	+	‡	‡	0	−	+	+	131	+	+	‡	3	×
20	‡	‡	9	#	+	+	103	×	‡	‡	11	×	+	+	107	×	−	‡	3	×
21	‡	‡	1	×	‡	‡	11	+	‡	‡	4	×	+	+	94	+	−	‡	7	+
22	‡	‡	2	×	+	+	34	×	‡	‡	3	×	+	+	106	+	−	‡	0	#
23	‡	‡	0	−	+	+	147	+	‡	‡	15	×	‡	‡	10	×	−	‡	3	×
24	‡	‡	1	×	−	‡	2	−	‡	‡	3	−	+	‡	4	×	‡	‡	4	×
	Yield From Diseased Seed 156 lbs.				Yield From Healthy Seed 998 lbs.				Yield From Diseased Seed 184 lbs.				Yield From Healthy Seed 1369 lbs.				Yield From Diseased Seed 187 lbs.			

The plus sign (+) indicates a healthy stool; the double plus sign (‡), a diseased stool; the times sign (×), a partly diseased stool; the number sign (#), a wholly diseased stool; and the minus sign ( ), a missing stool.

TABLE VI

Stool	1				2				3				4				5			
Line	Feb. 1,1921	Apr. 22,1921	Yield June 6,1922	Aug. 15,1922	Feb. 1,1921	Apr. 22,1921	Yield June 6,1922	Aug. 15,1922	Feb. 1,1921	Apr. 22,1921	Yield June 6,1922	Aug. 15,1922	Feb. 1,1921	Apr. 22,1921	Yield June 6,1922	Aug. 15,1922	Feb. 1,1921	Apr. 22,1921	Yield June 6,1922	Aug. 15,1922
1	+	ǂ	0	#	ǂ	ǂ	0	−	ǂ	ǂ	0	+	+	+	0	#	+	+	0	−
2	+	ǂ	164	#	ǂ	ǂ	11	#	+	ǂ	131	#	ǂ	ǂ	0	−	+	ǂ	26	#
3	+	ǂ	86	x	ǂ	ǂ	50	#	+	ǂ	87	#	ǂ	ǂ	4	#	+	+	21	+
4	+	ǂ	119	#	ǂ	ǂ	0	−	+	ǂ	127	x	ǂ	ǂ	43	x	+	ǂ	192	x
5	+	ǂ	68	x	ǂ	ǂ	101	x	+	ǂ	67	#	−	−	0	−	+	ǂ	59	+
6	+	+	11	x	ǂ	ǂ	14	#	+	ǂ	168	#	+	+	9	#	+	ǂ	68	#
7	+	+	71	+	ǂ	ǂ	8	#	+	ǂ	18	#	+	+	86	+	+	ǂ	13	#
8	+	ǂ	52	−	ǂ	ǂ	34	#	+	ǂ	89	#	ǂ	ǂ	18	+	+	ǂ	29	#
9	+	+	49	−	ǂ	ǂ	41	+	+	+	6	x	ǂ	ǂ	20	+	+	ǂ	165	+
10	+	+	0	−	+	+	89	+	+	+	26	x	ǂ	ǂ	41	−	+	ǂ	84	x
11	+	+	55	x	ǂ	ǂ	14	−	+	+	6	x	ǂ	ǂ	17	−	+	+	76	+
12	+	ǂ	11	−	ǂ	ǂ	19	#	+	ǂ	70	+	ǂ	ǂ	0	−	+	ǂ	66	#
13	+	ǂ	0	#	+	+	0	x	+	+	10	x	ǂ	ǂ	28	+	+	ǂ	261	#
14	+	ǂ	70	#	ǂ	ǂ	38	#	+	ǂ	84	−	ǂ	ǂ	141	−	+	ǂ	162	#
15	+	ǂ	76	x	ǂ	ǂ	3	−	+	ǂ	168	#	+	+	0	#	+	ǂ	71	+
16	+	ǂ	36	#	ǂ	ǂ	0	#	+	ǂ	145	#	ǂ	ǂ	36	#	+	ǂ	4	#
17	+	+	0	x	ǂ	ǂ	0	#	+	ǂ	26	#	ǂ	ǂ	24	#	+	ǂ	105	#
18	+	ǂ	0	−	ǂ	ǂ	18	−	+	ǂ	108	x	ǂ	ǂ	85	#	+	ǂ	55	#
19	+	ǂ	0	#	ǂ	ǂ	0	+	+	ǂ	63	+	ǂ	ǂ	51	#	+	ǂ	61	x
20	+	ǂ	148	#	ǂ	ǂ	36	−	+	+	52	x	ǂ	ǂ	3	−	+	ǂ	194	#
21	+	ǂ	79	x	ǂ	ǂ	7	−	+	ǂ	196	x	ǂ	ǂ	29	#	+	ǂ	35	#
22	+	ǂ	27	x	ǂ	ǂ	25	+	+	+	82	x	ǂ	ǂ	0	−	+	+	89	#
23	+	ǂ	42	x	−	−	0	#	+	ǂ	29	x	−	−	0	−	+	ǂ	71	+
24	+	ǂ	193	+	ǂ	ǂ	9	−	+	ǂ	31	−	ǂ	ǂ	15	−	+	ǂ	41	#
	Yield From Healthy Seed 1357 lbs.				Yield From Diseased Seed 517 lbs.				Yield From Healthy Seed 1789 lbs.				Yield From Diseased Seed 650 lbs.				Yield From Healthy Seed 1948 lbs.			

Reaction of the variety Yellow Caledonia to mosaic in the experiment at Waialua.

TABLE VI—Continued

Stool	6				7				8				9				10			
Line	Feb. 1,1921	Apr. 22,1921	Yield June 6,1922	Aug. 15,1922	Feb. 1,1921	Apr. 22,1921	Yield June 6,1922	Aug. 15,1922	Feb. 1,1921	Apr. 22,1921	Yield June 6,1922	Aug. 15,1922	Feb. 1,1921	Apr. 22,1921	Yield June 6,1922	Aug. 15,1922	Feb. 1,1921	Apr. 22,1921	Yield June 6,1922	Aug. 15,1922
1	‡	‡	12	×	+	‡	30	#	‡	‡	30	×	+	‡	89	#	+	+	25	+
2	‡	‡	32	+	+	+	23	+	‡	‡	3	#	+	‡	23	×	‡	‡	8	#
3	‡	‡	0	—	+	+	16	+	‡	‡	75	—	+	‡	10	+	‡	‡	17	—
4	‡	‡	6	—	+	‡	66	#	‡	‡	5	#	+	+	23	+	‡	‡	23	#
5	‡	‡	14	×	+	+	54	#	‡	‡	0	×	+	+	142	#	‡	‡	7	×
6	‡	‡	36	#	+	+	46	×	‡	‡	9	—	+	‡	33	#	‡	‡	22	×
7	‡	‡	13	+	+	+	11	+	‡	‡	64	×	+	‡	36	#	+	+	25	—
8	‡	‡	10	+	+	+	61	+	‡	‡	38	#	—	—	0	—	‡	‡	0	—
9	‡	‡	14	—	+	‡	44	#	‡	‡	0	—	+	+	283	#	‡	‡	11	#
10	—	—	0	—	+	‡	35	×	‡	‡	46	—	+	‡	27	#	‡	‡	0	#
11	‡	‡	0	—	+	+	105	×	‡	‡	5	—	+	‡	176	+	‡	‡	0	#
12	‡	‡	14	—	+	‡	73	#	‡	‡	0	—	+	+	85	×	‡	‡	0	—
13	‡	‡	20	#	+	‡	56	×	‡	‡	50	+	+	‡	80	×	‡	‡	0	#
14	‡	‡	0	—	+	‡	96	×	‡	‡	0	—	+	‡	22	+	‡	‡	0	—
15	‡	‡	6	—	+	‡	127	#	‡	‡	21	#	+	‡	26	#	‡	‡	20	#
16	‡	‡	83	×	+	‡	19	—	—	—	0	—	+	+	46	+	‡	‡	17	#
17	‡	‡	22	#	+	‡	186	#	‡	‡	0	—	+	‡	112	+	‡	‡	6	#
18	‡	‡	9	—	+	‡	44	#	‡	‡	21	#	+	+	76	#	‡	‡	0	—
19	‡	‡	160	#	+	+	15	#	—	—	0	—	+	‡	73	#	‡	‡	0	#
20	‡	‡	3	—	+	‡	209	—	‡	‡	0	—	+	+	51	×	‡	‡	3	×
21	—	—	0	—	+	+	46	×	‡	‡	16	—	+	+	201	#	‡	‡	55	#
22	‡	‡	38	+	+	‡	46	#	‡	‡	19	#	+	‡	62	#	‡	‡	12	—
23	‡	‡	43	#	+	‡	182	#	‡	‡	65	—	+	‡	5	#	‡	‡	50	—
24	—	—	0	—	+	+	26	+	‡	‡	0	—	+	+	222	+	‡	‡	0	+
	Yield From Diseased Seed 535 lbs.				Yield From Healthy Seed 1616 lbs.				Yield From Diseased Seed 467 lbs.				Yield From Healthy Seed 1903 lbs.				Yield From Diseased Seed 301 lbs.			

The plus sign (+) indicates a healthy stool; the double plus sign (‡), a diseased stool; the times sign (×), a partly diseased stool; the number sign (#), a wholly diseased stool; and the minus sign (—), a missing stool.

TABLE VII

Stool	1				2				3				4				5			
Line	Feb. 1, 1921	Apr. 22, 1921	Yield June 6, 1922	Aug. 15, 1922	Feb. 1, 1921	Apr. 22, 1921	Yield June 6, 1922	Aug. 15, 1922	Feb. 1, 1921	Apr. 22, 1921	Yield June 6, 1922	Aug. 15, 1922	Feb. 1, 1921	Apr. 22, 1921	Yield June 6, 1922	Aug. 15, 1922	Feb. 1, 1921	Apr. 22, 1921	Yield June 6, 1922	Aug. 15, 1922
1	+	‡	205	#	‡	‡	85	#	+	‡	140	#	‡	‡	23	#	+	‡	95	#
2	+	‡	111	#	‡	‡	31	#	+	‡	38	−	‡	‡	33	#	+	‡	62	#
3	+	+	65	−	‡	‡	11	#	+	+	80	×	‡	‡	71	#	+	+	99	×
4	+	+	115	×	‡	‡	27	#	+	‡	51	+	‡	‡	65	−	+	+	57	+
5	+	+	26	+	‡	‡	110	×	+	‡	106	#	‡	‡	49	#	+	‡	27	+
6	+	‡	56	#	‡	‡	83	#	+	‡	42	#	‡	‡	0	−	+	‡	0	−
7	+	‡	49	#	‡	‡	84	#	+	‡	77	#	‡	‡	44	#	+	+	75	×
8	+	‡	104	×	‡	‡	15	#	+	‡	41	#	‡	‡	20	#	+	+	137	×
9	+	‡	100	×	‡	‡	69	#	−	−	0	−	‡	‡	40	#	+	‡	41	#
10	+	+	139	×	‡	‡	51	#	+	‡	91	#	‡	‡	45	#	+	+	117	×
11	+	‡	150	×	‡	‡	20	#	+	‡	36	×	‡	‡	60	#	+	‡	38	#
12	+	+	60	#	‡	‡	34	#	+	‡	164	#	‡	‡	37	−	+	+	142	×
13	+	‡	149	×	‡	‡	1	−	+	‡	125	#	‡	‡	50	×	+	+	114	×
14	+	+	202	+	‡	‡	80	#	+	+	120	×	‡	‡	31	#	+	+	99	+
15	+	‡	40	#	‡	‡	27	#	+	‡	112	#	‡	‡	55	×	+	‡	25	#
16	+	+	41	×	‡	‡	51	#	+	+	85	×	‡	‡	11	#	+	‡	40	#
17	+	+	72	#	‡	‡	83	#	+	‡	49	#	‡	‡	55	#	+	‡	64	#
18	+	‡	85	×	‡	‡	27	#	+	+	76	×	‡	‡	52	#	+	+	100	×
19	+	‡	0	#	‡	‡	51	#	+	+	56	+	‡	‡	0	#	+	+	80	+
20	+	‡	233	#	‡	‡	65	#	+	‡	48	×	‡	‡	42	−	+	‡	61	#
21	+	+	112	+	‡	‡	74	#	+	+	62	×	‡	‡	96	#	+	‡	21	×
22	+	‡	198	×	‡	‡	45	#	+	‡	48	#	‡	‡	39	#	+	‡	45	−
23	+	+	72	×	‡	‡	86	#	+	‡	13	×	‡	−	0	−	+	‡	87	×
24	+	+	0	×	‡	‡	89	#	+	+	54	#	‡	‡	54	#	+	‡	155	#
	Yield From Healthy Seed 2384 lbs.				Yield From Diseased Seed 1299 lbs.				Yield From Healthy Seed 1714 lbs.				Yield From Diseased Seed 972 lbs.				Yield From Healthy Seed 1781 lbs.			

Reaction of the variety Hawaii 109 to mosaic in the experiment at Waialua.

TABLE VII—Continued

Stool	6				7				8				9				10			
Line	Feb. 1, 1921	Apr. 22, 1921	Yield June 6, 1922	Aug. 15, 1922	Feb. 1, 1921	Apr. 22, 1921	Yield June 6, 1922	Aug. 15, 1922	Feb. 1, 1921	Apr. 22, 1921	Yield June 6, 1922	Aug. 15, 1922	Feb. 1, 1921	Apr. 22, 1921	Yield June 6, 1922	Aug. 15, 1922	Feb. 1, 1921	Apr. 22, 1921	Yield June 6, 1922	Aug. 15, 1922
1	‡	‡	33	#	+	+	25	×	‡	‡	48	#	+	+	56	×	‡	‡	105	#
2	‡	‡	44	#	+	‡	70	#	‡	‡	34	#	+	+	100	×	‡	‡	33	#
3	‡	‡	22	#	+	‡	46	#	‡	‡	23	#	+	‡	65	#	‡	‡	100	×
4	‡	‡	123	#	+	+	50	×	‡	‡	69	#	+	+	65	×	‡	‡	23	#
5	‡	‡	24	#	+	‡	90	×	‡	‡	51	#	+	+	70	+	‡	‡	79	×
6	‡	‡	65	#	+	‡	55	#	‡	‡	36	×	+	+	69	+	‡	‡	90	#
7	‡	‡	35	#	+	+	60	+	‡	‡	27	#	+	‡	30	#	‡	‡	69	#
8	‡	‡	35	#	+	+	56	+	‡	‡	55	#	+	‡	49	#	‡	‡	82	#
9	‡	‡	124	—	+	‡	41	#	‡	‡	51	#	+	+	45	×	‡	‡	49	#
10	+	+	32	#	+	+	102	#	+	+	17	#	+	‡	122	#	—	—	0	—
11	‡	‡	94	×	+	+	91	×	‡	‡	72	#	+	‡	80	#	‡	‡	85	#
12	‡	‡	9	#	+	‡	41	#	‡	‡	75	×	+	‡	35	#	‡	‡	60	×
13	‡	‡	54	#	+	‡	115	#	‡	‡	77	#	+	‡	50	#	‡	‡	66	#
14	+	+	0	—	+	‡	116	×	‡	‡	35	×	—	—	0	—	‡	‡	35	#
15	‡	‡	39	#	+	‡	28	#	‡	‡	55	#	+	+	105	×	‡	‡	0	#
16	‡	‡	90	#	+	+	50	+	‡	‡	37	×	+	‡	51	#	‡	‡	70	×
17	‡	‡	80	#	+	+	140	+	‡	‡	35	×	+	‡	26	#	‡	‡	52	#
18	‡	‡	39	#	+	+	62	×	‡	‡	41	×	+	‡	96	#	‡	‡	65	#
19	‡	‡	10	#	+	+	66	×	‡	‡	49	#	+	‡	126	×	‡	‡	39	#
20	‡	‡	36	—	+	‡	110	#	‡	‡	64	#	+	‡	128	×	‡	‡	83	×
21	‡	‡	45	#	+	+	75	#	‡	‡	54	#	+	+	85	+	‡	‡	0	×
22	‡	‡	49	#	+	+	82	+	‡	‡	107	+	+	+	51	+	‡	‡	0	#
23	‡	‡	88	—	+	‡	109	#	‡	‡	31	#	+	+	103	×	‡	‡	0	#
24	‡	‡	30	#	+	+	45	×	‡	‡	17	#	+	‡	103	×	‡	‡	0	×
	Yield From Diseased Seed 1200 lbs.				Yield From Healthy Seed 1725 lbs.				Yield From Diseased Seed 1160 lbs.				Yield From Healthy Seed 1710 lbs.				Yield From Diseased Seed 1185 lbs.			

The plus sign (+) indicates a healthy stool; the double plus sign (‡), a diseased stool; the times sign (×), a partly diseased stool; the number sign (#), a wholly diseased stool; and the minus sign (—), a missing stool.

TABLE VIII

Stool	1				2				3				4				5			
Line	Feb. 1,1921	Apr. 22,1921	Yield June 6,1922	Aug. 15,1922	Feb. 1,1921	Apr. 22,1921	Yield June 6,1922	Aug. 15,1922	Feb. 1,1921	Apr. 22,1921	Yield June 6,1922	Aug. 15,1922	Feb. 1,1921	Apr. 22,1921	Yield June 6,1922	Aug. 15,1922	Feb. 1,1921	Apr. 22,1921	Yield June 6,1922	Aug. 15,1922
1	+	‡	40	✱	‡	‡	55	✱	+	‡	173	✱	‡	‡	65	✱	–	–	0	–
2	+	‡	20	✱	‡	‡	5	–	+	‡	44	✱	‡	‡	44	✱	+	‡	53	×
3	–	–	0	–	‡	‡	33	✱	+	‡	152	✱	–	–	0	✱	+	‡	39	+
4	–	–	0	–	‡	‡	32	✱	+	‡	14	✱	–	–	0	✱	+	‡	54	✱
5	+	‡	128	✱	‡	‡	56	✱	+	‡	46	✱	–	–	0	–	–	–	0	–
6	+	‡	5	–	‡	‡	65	✱	+	‡	98	✱	‡	‡	11	–	+	‡	79	✱
7	+	‡	110	✱	‡	‡	12	×	+	‡	60	✱	‡	‡	71	✱	–	–	0	–
8	+	‡	45	–	‡	‡	17	–	+	‡	51	–	‡	‡	16	–	+	‡	126	✱
9	+	‡	57	✱	‡	‡	98	–	+	‡	44	✱	‡	‡	47	✱	+	+	94	+
10	–	–	0	✱	‡	‡	72	–	+	‡	59	–	‡	‡	17	–	+	‡	20	–
11	+	+	66	+	‡	‡	71	✱	–	–	0	–	‡	‡	65	✱	+	‡	80	✱
12	+	‡	144	×	‡	‡	13	✱	+	‡	60	✱	‡	‡	34	–	+	‡	65	✱
13	+	‡	26	✱	‡	‡	5	–	+	‡	46	–	‡	‡	24	✱	+	‡	16	–
14	+	+	121	+	‡	‡	16	✱	+	‡	43	✱	‡	‡	10	–	+	‡	34	–
15	+	‡	21	✱	‡	‡	21	✱	+	‡	35	✱	‡	‡	26	✱	+	‡	17	✱
16	+	‡	1	✱	‡	‡	14	✱	+	‡	42	✱	‡	‡	31	✱	+	‡	0	✱
17	+	‡	51	✱	‡	‡	34	✱	+	‡	20	–	‡	‡	45	✱	+	‡	79	✱
18	+	‡	46	✱	‡	‡	103	–	+	‡	50	–	‡	‡	31	×	+	‡	34	–
19	+	‡	34	✱	‡	‡	48	–	–	–	0	–	‡	‡	34	✱	+	‡	42	–
20	–	–	0	–	–	–	0	–	+	‡	67	–	‡	‡	50	✱	+	‡	33	✱
21	+	‡	84	✱	‡	‡	11	✱	+	‡	24	✱	‡	‡	76	✱	+	‡	62	✱
22	+	+	0	+	‡	‡	7	–	+	‡	61	✱	‡	‡	62	–	–	–	0	–
23	+	‡	96	–	‡	‡	64	✱	+	‡	75	✱	‡	‡	57	✱	–	–	0	–
24	+	‡	84	×	‡	‡	0	✱	+	‡	89	✱	‡	‡	77	✱	+	‡	47	✱
	Yield From Healthy Seed 1179 lbs.				Yield From Diseased Seed 852 lbs.				Yield From Healthy Seed 1353 lbs.				Yield From Diseased Seed 893 lbs.				Yield From Healthy Seed 974 lbs.			

Reaction of the variety Lahaina to mosaic in the experiment at Waialua.

TABLE VIII—Continued

Stool / Line	6 Feb. 1, 1921	6 Apr. 22, 1921	6 Yield June 6, 1922	6 Aug. 15, 1922	7 Feb. 1, 1921	7 Apr. 22, 1921	7 Yield June 6, 1922	7 Aug. 15, 1922	8 Feb. 1, 1921	8 Apr. 22, 1921	8 Yield June 6, 1922	8 Aug. 15, 1922	9 Feb. 1, 1921	9 Apr. 22, 1921	9 Yield June 6, 1922	9 Aug. 15, 1922	10 Feb. 1, 1921	10 Apr. 22, 1921	10 Yield June 6, 1922	10 Aug. 15, 1922
1	‡	‡	0	#	+	‡	54	#	‡	‡	78	#	+	‡	40	#	‡	‡	0	#
2	‡	‡	52	#	+	‡	38	#	‡	‡	0	#	+	‡	74	+	‡	‡	36	#
3	‡	‡	8	#	+	‡	54	#	‡	‡	11	#	+	‡	54	+	‡	‡	24	#
4	‡	‡	21	#	−	−	0	−	‡	‡	34	#	−	−	0	#	‡	‡	22	#
5	‡	‡	35	#	+	‡	26	#	‡	‡	64	#	−	−	0	−	‡	‡	56	#
6	‡	‡	29	#	+	‡	31	#	‡	‡	38	#	+	‡	37	−	‡	‡	61	#
7	‡	‡	21	#	+	‡	44	#	‡	‡	110	#	−	−	0	#	‡	‡	24	#
8	‡	‡	59	−	+	‡	36	#	‡	‡	64	#	−	−	0	−	‡	‡	35	#
9	‡	‡	50	−	−	−	0	−	‡	‡	50	#	+	‡	121	#	‡	‡	41	#
10	‡	‡	21	−	+	‡	47	−	‡	‡	17	−	+	‡	9	−	‡	‡	51	−
11	‡	‡	47	#	−	−	0	−	‡	‡	49	#	−	−	0	−	−	−	0	−
12	‡	‡	18	−	+	‡	172	×	‡	‡	0	−	+	‡	136	×	‡	‡	0	−
13	‡	‡	5	−	+	‡	161	×	−	−	0	−	−	−	0	−	‡	‡	80	#
14	‡	‡	44	−	+	‡	6	−	‡	‡	41	−	+	‡	59	#	‡	‡	21	#
15	‡	‡	43	#	−	−	0	−	‡	‡	31	#	+	‡	50	#	‡	‡	32	#
16	‡	‡	6	−	+	‡	102	#	‡	‡	0	−	+	‡	106	#	‡	‡	37	−
17	‡	‡	0	−	+	‡	70	#	‡	‡	15	−	+	‡	46	−	‡	‡	17	−
18	‡	‡	71	−	+	‡	56	−	−	−	0	−	+	‡	96	−	‡	‡	64	#
19	‡	‡	29	#	+	‡	84	#	‡	‡	26	−	+	‡	97	#	‡	‡	42	#
20	‡	‡	21	#	+	‡	37	#	‡	‡	10	−	+	‡	68	#	‡	‡	0	#
21	‡	‡	34	#	+	‡	24	−	‡	‡	58	−	−	−	0	−	‡	‡	71	#
22	‡	‡	41	#	+	‡	90	−	‡	‡	65	−	+	‡	29	×	‡	‡	66	#
23	‡	‡	113	#	−	−	0	−	‡	‡	57	#	+	‡	78	#	‡	‡	74	#
24	‡	‡	48	#	+	‡	104	#	‡	‡	54	#	+	‡	60	#	‡	‡	0	#
	Yield From Diseased Seed 816 lbs.				Yield From Healthy Seed 1236 lbs.				Yield From Diseased Seed 872 lbs.				Yield From Healthy Seed 1160 lbs.				Yield From Diseased Seed 854 lbs.			

The plus sign (+) indicates a healthy stool; the double plus sign (‡), a diseased stool; the times sign (×), a partly diseased stool; the number sign (#), a wholly diseased stool; and the minus sign (—), a missing stool.

TABLE IX

Stool	1				2				3				4				5			
Line	Feb. 1,1921	Apr. 22,1921	Yield June 6,1922	Aug. 15,1922	Feb. 1,1921	Apr. 22,1921	Yield June 6,1922	Aug. 15,1922	Feb. 1,1921	Apr. 22,1921	Yield June 6,1922	Aug. 15,1922	Feb. 1,1921	Apr. 22,1921	Yield June 6,1922	Aug. 15,1922	Feb. 1,1921	Apr. 22,1921	Yield June 6,1922	Aug. 15,1922
1	+	+	102	×	ǂ	ǂ	36	×	+	ǂ	78	×	ǂ	ǂ	48	×	+	ǂ	43	×
2	+	ǂ	80	×	ǂ	ǂ	25	×	+	ǂ	77	×	ǂ	ǂ	55	×	+	ǂ	74	×
3	+	ǂ	126	×	ǂ	ǂ	24	×	+	ǂ	55	×	ǂ	ǂ	71	×	+	ǂ	99	×
4	+	ǂ	98	×	ǂ	ǂ	22	×	+	ǂ	64	×	ǂ	ǂ	16	×	+	ǂ	165	×
5	+	ǂ	64	×	ǂ	ǂ	36	×	+	ǂ	111	×	ǂ	ǂ	24	×	+	ǂ	34	✱
6	+	ǂ	126	×	ǂ	ǂ	45	×	+	ǂ	64	−	ǂ	ǂ	0	−	+	ǂ	46	×
7	+	ǂ	119	×	ǂ	ǂ	65	×	−	−	0	−	−	−	0	−	+	+	58	×
8	+	ǂ	44	×	−	−	0	−	+	ǂ	96	×	ǂ	ǂ	54	×	+	ǂ	11	×
9	+	ǂ	14	−	ǂ	ǂ	49	×	+	ǂ	45	+	ǂ	ǂ	12	×	+	ǂ	11	×
10	+	ǂ	85	×	ǂ	ǂ	11	×	+	ǂ	65	+	ǂ	ǂ	84	×	+	ǂ	72	×
11	+	ǂ	4	+	−	−	0	−	+	ǂ	154	×	ǂ	ǂ	107	+	+	ǂ	45	×
12	+	ǂ	55	×	ǂ	ǂ	21	×	+	ǂ	57	×	ǂ	ǂ	52	×	+	ǂ	82	+
13	+	+	80	+	ǂ	ǂ	44	×	+	ǂ	65	×	ǂ	ǂ	64	×	+	ǂ	84	+
14	+	ǂ	38	×	ǂ	ǂ	56	×	+	ǂ	34	×	ǂ	ǂ	61	×	+	ǂ	62	×
15	+	+	90	×	ǂ	ǂ	64	×	+	ǂ	63	×	ǂ	ǂ	70	×	+	ǂ	61	×
16	+	ǂ	51	×	ǂ	ǂ	34	×	−	−	0	−	ǂ	ǂ	97	+	+	ǂ	86	×
17	+	ǂ	66	×	ǂ	ǂ	40	×	+	ǂ	154	×	−	−	0	−	+	ǂ	54	×
18	+	ǂ	44	×	ǂ	ǂ	64	×	+	ǂ	56	×	ǂ	ǂ	34	×	+	ǂ	73	✱
19	+	−	0	−	ǂ	ǂ	14	×	+	ǂ	63	×	ǂ	ǂ	15	−	+	ǂ	101	×
20	+	ǂ	67	×	ǂ	ǂ	72	×	+	+	94	+	ǂ	ǂ	46	×	+	ǂ	66	×
21	−	−	0	−	ǂ	ǂ	48	×	+	ǂ	49	+	ǂ	ǂ	26	×	+	ǂ	63	×
22	+	ǂ	109	×	ǂ	ǂ	29	×	+	ǂ	105	+	ǂ	ǂ	81	×	+	ǂ	30	✱
23	+	ǂ	25	+	ǂ	ǂ	72	×	+	ǂ	81	×	ǂ	ǂ	62	×	+	ǂ	44	×
24	−	−	0	X	ǂ	ǂ	80	×	+	ǂ	79	×	ǂ	ǂ	49	×	+	ǂ	101	×
	Yield From Healthy Seed 1487 lbs.				Yield From Diseased Seed 951 lbs.				Yield From Healthy Seed 1709 lbs.				Yield From Diseased Seed 1128 lbs.				Yield From Healthy Seed 1565 lbs.			

Reaction of the variety Demerara 1135 to mosaic in the experiment at Waialua.

TABLE IX—Continued

Stool	6				7				8				9				10			
Line	Feb. 1,1921	Apr. 22,1921	Yield June 6,1922	Aug. 15,1922	Feb. 1,1921	Apr. 22,1921	Yield June 6,1922	Aug. 15,1922	Feb. 1,1921	Apr. 22,1921	Yield June 6,1922	Aug. 15,1922	Feb. 1,1921	Apr. 22,1921	Yield June 6,1922	Aug. 15,1922	Feb. 1,1921	Apr. 22,1921	Yield June 6,1922	Aug. 15,1922
1	‡	‡	30	–	+	+	27	×	‡	‡	0	–	+	‡	95	+	–	–	0	–
2	‡	‡	50	×	+	‡	128	×	‡	‡	47	×	+	‡	82	×	–	–	0	–
3	‡	‡	31	×	+	‡	101	×	‡	‡	64	×	+	‡	0	×	‡	‡	0	×
4	‡	‡	21	×	+	‡	103	×	‡	‡	27	×	+	‡	81	×	‡	‡	54	×
5	‡	‡	109	×	+	‡	41	×	‡	‡	76	×	+	‡	54	×	‡	‡	17	×
6	‡	‡	68	#	–	–	0	×	‡	‡	94	×	+	‡	65	+	–	–	0	–
7	‡	‡	44	×	+	‡	83	×	‡	‡	20	×	+	‡	28	×	‡	‡	83	×
8	‡	‡	76	×	+	‡	66	–	‡	‡	6	–	+	‡	76	+	‡	‡	75	×
9	‡	‡	11	×	+	‡	98	×	‡	‡	39	×	+	+	97	×	‡	‡	33	×
10	‡	‡	75	×	+	‡	89	×	‡	‡	21	×	+	+	136	×	‡	‡	22	×
11	–	–	0	–	+	+	68	×	‡	‡	14	×	+	+	157	+	‡	‡	0	×
12	‡	‡	49	×	+	+	97	×	‡	‡	34	×	–	–	0	–	‡	‡	34	×
13	‡	‡	61	×	+	‡	49	×	‡	‡	61	×	+	‡	14	×	‡	‡	64	×
14	‡	‡	65	×	+	‡	88	×	‡	‡	46	×	+	‡	15	×	‡	‡	72	×
15	‡	‡	43	×	+	‡	32	×	‡	‡	62	×	+	‡	91	×	–	–	0	–
16	‡	‡	74	×	+	‡	51	×	‡	‡	74	×	+	‡	62	×	‡	‡	82	×
17	‡	+	4	×	+	‡	34	+	‡	‡	47	+	+	‡	20	×	‡	‡	38	×
18	‡	‡	102	×	+	‡	59	×	‡	‡	97	×	+	‡	41	×	‡	‡	70	×
19	‡	‡	51	×	+	‡	91	×	‡	‡	63	×	+	‡	46	×	‡	‡	34	+
20	‡	‡	62	×	+	‡	56	×	‡	‡	28	×	+	‡	57	×	‡	‡	0	×
21	‡	‡	39	#	+	‡	64	×	‡	‡	35	×	+	‡	22	×	‡	‡	82	+
22	‡	‡	48	×	+	‡	83	×	‡	‡	26	×	+	‡	24	×	‡	‡	60	×
23	‡	‡	33	×	+	‡	64	×	‡	‡	59	×	+	‡	64	×	‡	‡	74	×
24	‡	‡	29	×	+	‡	24	+	‡	‡	43	+	+	+	32	×	‡	‡	41	+
	Yield From Diseased Seed 1175 lbs.				Yield From Healthy Seed 1596 lbs.				Yield From Diseased Seed 1083 lbs.				Yield From Healthy Seed 1359 lbs.				Yield From Diseased Seed 935 lbs.			

The plus sign (+) indicates a healthy stool; the double plus sign (‡), a diseased stool; the times sign (×), a partly diseased stool; the number sign (#), a wholly diseased stool; and the minus sign (—), a missing stool.

TABLE X

Stool	1				2				3				4				5			
Line	Feb. 1, 1921	Apr. 22, 1921	Yield June 6, 1922	Aug. 15, 1922	Feb. 1, 1921	Apr. 22, 1921	Yield June 6, 1922	Aug. 15, 1922	Feb. 1, 1921	Apr. 22, 1921	Yield June 6, 1922	Aug. 15, 1922	Feb. 1, 1921	Apr. 22, 1921	Yield June 6, 1922	Aug. 15, 1922	Feb. 1, 1921	Apr. 22, 1921	Yield June 6, 1922	Aug. 15, 1922
1	+	‡	145	#	‡	‡	41	#	+	‡	0	#	‡	‡	39	#	+	‡	77	#
2	+	‡	97	#	‡	‡	52	#	+	‡	51	#	‡	‡	73	#	+	‡	21	#
3	–	–	0	–	‡	‡	65	#	+	‡	19	#	‡	‡	19	#	+	‡	62	#
4	+	‡	108	#	‡	‡	39	#	+	‡	69	#	‡	‡	0	–	+	‡	96	#
5	–	–	0	–	‡	‡	34	#	+	‡	66	#	‡	‡	13	#	+	‡	71	#
6	+	‡	106	#	‡	‡	0	#	+	‡	81	#	‡	‡	44	#	+	‡	59	#
7	–	–	0	–	‡	‡	42	#	+	‡	57	#	‡	‡	96	#	+	‡	56	#
8									+	‡	121	#	‡	‡	55	#	+	‡	73	#
9													‡	‡	56	#	+	‡	137	#
10													‡	‡	29	#	+	‡	106	#
11													‡	‡	59	#	+	‡	43	#
12																	+	‡	108	#
13																	+	‡	112	#
14																	+	‡	127	#
15					‡	‡	72	#									+	‡	51	#
16					‡	‡	65	#									+	‡	72	#
17					‡	‡	76	#									+	‡	73	#
18					‡	‡	87	#	+	+	67	#								
19					‡	‡	83	#	+	‡	28	#								
20					‡	‡	64	#	+	‡	84	#	‡	‡	41	#				
21					‡	‡	0	–	+	‡	54	#	‡	‡	101	#				
22					‡	‡	0	–	+	‡	71	#	‡	‡	35	#				
23					‡	‡	0	#	+	‡	115	#	‡	‡	26	#				
24					‡	‡	55	#	+	‡	96	#	‡	‡	190	#				
	Yield From Healthy Seed 456 lbs.				Yield From Diseased Seed 775 lbs.				Yield From Healthy Seed 979 lbs.				Yield From Diseased Seed 876 lbs.				Yield From Healthy Seed 1344 lbs.			

Reaction of the variety Demerara 117 to mosaic in the experiment at Waialua.

Because of lack of space, only eighty-seven hills were planted with healthy seed, and one hundred two hills with diseased seed.

TABLE X—Continued

Stool	6				7				8				9				10			
Line	Feb. 1,1921	Apr. 22,1921	Yield June 6,1922	Aug. 15,1922	Feb. 1,1921	Apr. 22,1921	Yield June 6,1922	Aug. 15,1922	Feb. 1,1921	Apr. 22,1921	Yield June 6,1922	Aug. 15,1922	Feb. 1,1921	Apr. 22,1921	Yield June 6,1922	Aug. 15,1922	Feb. 1,1921	Apr. 22,1921	Yield June 6,1922	Aug. 15,1922
1	‡	‡	38	–	+	‡	0	#	‡	‡	33	–	+	‡	50	#	‡	‡	57	#
2	‡	‡	50	#	+	‡	42	#	‡	‡	27	–	+	‡	137	#	‡	‡	19	#
3	‡	‡	64	#	+	‡	30	#	‡	‡	38	#	+	‡	64	#	‡	‡	100	#
4	‡	‡	22	#	+	‡	62	#	‡	‡	95	#	+	‡	77	#	‡	‡	0	#
5	‡	‡	39	#	+	‡	53	#	‡	‡	38	#	+	‡	35	#	‡	‡	65	#
6	‡	‡	27	#	+	‡	68	#	‡	‡	36	#	+	‡	77	#	–	–	0	–
7	‡	‡	30	#	+	‡	52	#	‡	‡	44	#	+	‡	52	–	–	–	0	–
8	‡	‡	90	#	+	‡	63	#	‡	‡	52	#	+	‡	64	#	‡	‡	140	#
9	‡	‡	105	#	+	‡	60	#	‡	‡	8	#	+	‡	5	#	‡	‡	40	#
10	‡	‡	166	#	+	‡	156	#	‡	‡	120	#	+	‡	111	#	‡	‡	0	–
11	‡	‡	53	#	+	‡	77	#	‡	‡	30	#	+	‡	68	#	‡	‡	34	#
12	‡	‡	78	#	+	‡	33	#	‡	‡	96	#	+	‡	135	#	‡	‡	73	#
13	‡	‡	78	#	+	‡	56	#	‡	‡	52	#	+	‡	44	#	‡	‡	65	#
14	‡	‡	49	#	+	‡	45	#	‡	‡	12	#	+	‡	25	#	‡	‡	122	#
15	‡	‡	35	#	+	‡	33	#	‡	‡	16	#	+	‡	100	#	‡	‡	45	#
16	‡	‡	27	#	+	‡	74	#	‡	‡	137	#	+	‡	78	#	‡	‡	88	#
17	‡	‡	122	#	+	‡	76	#	‡	‡	169	#	+	‡	76	#	‡	‡	96	#
18	‡	‡	17	#	+	‡	61	#	‡	‡	14	#	+	‡	128	#	‡	‡	103	#
19	‡	‡	62	#	+	‡	46	#	‡	‡	67	#	+	‡	50	#	‡	‡	84	#
20	‡	‡	16	#	+	‡	0	–	‡	‡	37	#	+	‡	86	#	‡	‡	56	#
21	‡	‡	24	#	+	‡	83	#	‡	‡	51	#	+	‡	44	#	‡	‡	131	#
22					+	‡	63	#	‡	‡	86	#	+	‡	91	#	‡	‡	17	#
23					+	‡	128	#	‡	‡	48	#	+	‡	90	#	‡	‡	85	#
24					+	‡	63	#	‡	‡	41	#	+	‡	54	#	‡	‡	39	#
	Yield From Diseased Seed 1192 lbs.				Yield From Healthy Seed 1424 lbs.				Yield From Diseased Seed 1347 lbs.				Yield From Healthy Seed 1741 lbs.				Yield From Diseased Seed 1459 lbs.			

The plus sign (+) indicates a healthy stool; the double plus sign (‡), a diseased stool; the times sign (×), a partly diseased stool; the number sign (#), a wholly diseased stool; and the minus sign (—), a missing stool.

ninety-seven were still healthy on September 6, 1922. Of the hills planted with diseased seed, sixty were missing, three were partly diseased, and the remaining fifty-seven were wholly diseased. During the two years the experiment was under observation, fifteen of the stools from healthy seed became diseased. None of the stools from diseased seed showed complete recovery, but each of four of them gave one or more healthy shoots.

The reaction of the variety Demerara 1135 to mosaic in the experiment at Pearl City is shown in Table IV. Of the hills planted with healthy seed, two were missing, one was diseased and one hundred seventeen were still healthy when the cane was approximately seven months old; and, of the hills planted with diseased seed, one was missing, twenty-one were healthy and the remaining ninety-eight were diseased. The stools from healthy seed yielded 5,344 pounds of cane; the stools from diseased seed, only 3,130 pounds of cane. Of the hills planted with healthy seed, three were missing, two were partly diseased, and one hundred fifteen were still healthy two years after planting. Of the hills planted with diseased seed, three were missing, forty-five were partly diseased, two were wholly diseased, and seventy were healthy after the same period of time. During the course of the experiment, two healthy plants from healthy seed became diseased and forty-nine diseased plants from diseased seed recovered.

Table V shows the effect of mosaic on the variety Striped Tip in the experiment at Pearl City. Of the hills planted with healthy seed, four were missing, thirty-six were diseased and eighty were healthy; and of the hills planted with diseased seed, three were missing, two were healthy and one hundred fifteen were diseased on April 28, 1921, when the cane was approximately seven months old. The stools from healthy seed yielded 4,386 pounds of cane, while the stools from diseased seed yielded only 941 pounds of cane. Of the hills from healthy seed, ten were missing, sixty were partly diseased, three were wholly diseased, and forty-seven were still healthy at the end of two years. Of the hills from diseased seed, twenty-five were missing, sixty-six were partly diseased, eight were wholly diseased, and twenty-one were healthy after two years. During the course of the experiment, fifty healthy plants from healthy seed became diseased, and nineteen diseased plants from diseased seed recovered.

Tables VI to X inclusive show the effect of mosaic on the different varieties of cane grown in the experiment at Waialua. Table VI gives the reaction of the variety Yellow Caledonia. Of the one hundred twenty hills planted with healthy seed, one was missing, eighty-four were diseased and thirty-five were still healthy on April 22, 1921, when the cane was approximately five months old. Of the one hundred twenty hills planted with diseased seed, eight were missing, eight were healthy and one hundred four were diseased on the same date. The stools from healthy seed yielded 8,613 pounds while the stools from diseased seed yielded only 2,470 pounds. Of the hills from healthy seed, eleven were missing, thirty-two were partly diseased, fifty-four were wholly diseased, and twenty-three were still healthy after a period of twenty-one months. Of the hills from diseased seed, fifty-two were missing, twelve were partly diseased, forty-one were wholly diseased, and fifteen were healthy after twenty-one months. Eighty-five of the healthy plants from healthy seed became diseased. On the other hand, twelve of

the diseased stools from diseased seed recovered during the course of the experiment.

Table VII shows the effect of mosaic on the variety Hawaii 109 in the experiment at Waialua. Of the hills from healthy seed, two were missing, sixty-seven were diseased and fifty-one were still healthy after five months. Of the hills from diseased seed, two were missing, three were healthy, and one hundred fifteen were diseased after the same period of time. The stools from healthy seed yielded 9,314 pounds of cane, while the stools from diseased seed yielded only 5,816 pounds of cane. Of the hills from healthy seed, six were missing, forty-five were partly diseased, fifty-one were wholly diseased, and eighteen were still healthy after a period of twenty-one months. Of the hills from diseased seed, eleven were missing, seventeen were partly diseased, ninety-one were wholly diseased and one was healthy after the same period of time. During the time they were under observation, ninety-six of the healthy plants from healthy seed became diseased, and one diseased plant from diseased seed recovered.

The effect of mosaic on the variety Lahaina in the experiment at Waialua is shown in Table VIII. Of the hills from healthy seed, twenty-three were missing, ninety-three were diseased, and four were still healthy five months after planting. Of the hills from diseased seed, seven were missing and the remaining one hundred thirteen were diseased after five months. The stools from healthy seed yielded 5,902 pounds of cane, while those from diseased seed yielded only 4,287 pounds of cane. In the ratoon crop, observed August 15, 1922, forty-three of the hills planted with healthy seed were missing, seven were partly diseased, sixty-three were wholly diseased and seven were healthy. On the same date, forty-one of the hills planted with diseased seed were missing, two were partly diseased and seventy-seven were wholly diseased. During the course of the experiment, ninety-three healthy hills from healthy seed contracted the disease. None of the diseased stools from diseased seed showed complete recovery, but in the ratoon crop two of them had one or more healthy shoots.

Table IX shows the effect of mosaic on the variety Demerara 1135 in the experiment at Waialua. Of the hills from healthy seed, seven were missing, one hundred one were diseased and twelve were still healthy five months after planting. Of the hills from diseased seed, nine were missing, one was healthy and one hundred ten were diseased after five months. The stools from healthy seed yielded 7,716 pounds of cane, while the stools from the same quantity of diseased seed yielded only 5,272 pounds of cane. Of the hills from healthy seed, eight were missing, ninety-three were partly diseased, three were wholly diseased and sixteen were healthy in the young ratoon. Of the stools from diseased seed, fourteen were missing, ninety-seven were partly diseased, two were wholly diseased and seven were healthy in the ratoon crop. During the course of the experiment the disease spread to one hundred twelve of the healthy stools grown from healthy seed. Seven of the diseased stools grown from diseased seed recovered. Out of the one hundred ninety-five diseased stools in the young ratoon, only five were wholly diseased. Of the diseased stools from diseased seed, ninety-seven had one or more healthy shoots, and only two were wholly diseased.

The effect of mosaic on the variety Demerara 117 in the experiment at Waialua is shown in Table X. Because of lack of space, it was not possible to plant the full number of hills with this variety. Eighty-seven hills were planted with healthy seed, and one hundred two hills with diseased seed. Of the hills planted with healthy seed, three were missing, eighty-three were diseased and one was still healthy after a period of five months. Of the hills planted with diseased seed, two were missing and the remaining one hundred were diseased after the same period of time. The eighty-seven hills from healthy seed yielded 5,944 pounds, or an average of sixty-eight and one-third pounds per hill, while the one hundred two hills planted with diseased seed yielded only 5,649 pounds, or an average of fifty-five and one-third pounds per hill. Every shoot in every stool from both healthy and diseased seed was diseased August 15, 1922, when the experiment was ended.

From tables VI to X it will be seen that mosaic spread to most of the healthy hills of all of the varieties grown in the experiment at Waialua. In the three similar experiments at other points, there was very little spread to the healthy hills of the more resistant varieties, and only a moderate amount of spread to the healthy hills of susceptible varieties. Although most of the healthy stools in the experiment at Waialua became diseased when less than five months old, they, nevertheless, gave a much better yield than stools from diseased seed. Because of the extensive spread of the disease, the results, as regards the effect of mosaic on yield, are not as accurate in this experiment as in those where little spread occurred.

When the cane in the experiment at Waialua was quite small, there was, between the rows, a rank growth of the grasses *Chaetochloa verticillata* and *Eleusine indica*. Some of the plants of the latter had mosaic and were infested with the corn aphid. After a time the grasses were cut down, and it is believed that aphids going temporarily on to the cane caused wholesale spread of mosaic.

The results given in Tables I to X are summarized in Table XI, which shows the effect of mosaic on the different commercial varieties used in the two experiments. It gives, for each variety, the total yield of cane from healthy and from diseased seed, the extent to which the disease spread to healthy stools grown from healthy seed, and the degree of recovery shown by diseased stools grown from diseased seed. A study of the table shows that there are three important aspects of the reaction of cane varieties to mosaic. They are: resistance to infection, capacity to withstand the disease, and ability to recover from it. When the different varieties are considered from these points of view, some interesting facts are brought to light. In the experiment at Pearl City, only a small amount of spread to healthy stools occurred in the varieties Demerara 1135, Badila, and Hawaii 109. The greatest number of new infections occurred in the variety Striped Tip. A considerable amount of spread also took place in the variety Lahaina. If the different varieties be judged according to their behaviour in this experiment and are named in the order of their resistance to infection, the following sequence results: Demerara 1135, Badila, Hawaii 109, Lahaina, and Striped Tip. If they be judged by the results obtained in the experiment at Waialua they take a somewhat different order as follows: Yellow Caledonia, Hawaii 109, De-

TABLE XI

Variety	Badila	H109	Lahaina	D1135	Striped Tip	Yel. Cal.	H109	Lahaina	D1135	D117
Location Of Experiment	Pearl City	"	"	"	"	Waialua	"	"	"	"
Weight Of Cane From Hills Planted With Healthy Seed	5466 lbs.	5235 "	4947 "	5344 "	5386 "	8613 "	9314 "	5902 "	7716 "	5944 "
Weight Of Cane From Hills Planted With Diseased Seed	1196 lbs.	3330 "	1382 "	3130 "	941 "	2470 "	5816 "	4287 "	5272 "	5649 "
Average Weight Of Cane Per Hill From Healthy Seed	45.5 lbs.	43.6 "	41.2 "	44.5 "	44.8 "	71.7 "	77.6 "	49.1 "	64.3 "	68.3 "
Average Weight Of Cane Per Hill From Diseased Seed	9.9 lbs.	27.7 "	11.5 "	26.0 "	7.8 "	20.5 "	48.4 "	35.7 "	43.9 "	55.3 "
Number Of Missing Hills Planted With Healthy Seed	6	1	8	3	10	11	6	43	8	5
Number Of Partly Diseased Hills From Healthy Seed, Ratoon Crop	2	4	4	2	60	32	45	7	93	0
Number Of Wholly Diseased Hills From Healthy Seed, Ratoon Crop	1	1	11	0	3	54	51	63	3	82
Number Of Healthy Hills From Healthy Seed, Ratoon Crop	111	114	97	115	47	25	18	7	16	0
Number Of Healthy Hills From Healthy Seed That Became Diseased	3	5	15	2	50	85	96	93	112	82
Number Of Missing Hills Planted With Diseased Seed	34	11	60	3	25	52	11	41	14	9
Number Of Partly Diseased Hills From Diseased Seed, Ratoon Crop	30	30	3	45	66	12	17	2	97	0
Number Of Wholly Diseased Hills From Diseased Seed, Ratoon Crop	27	54	57	2	8	41	91	77	2	93
Number Of Healthy Hills From Diseased Seed, Ratoon Crop	29	25	0	70	21	15	1	0	7	0
Number Of Diseased Hills From Diseased Seed That Recovered	16	11	0	49	19	12	1	0	7	0
Total Number Of Hills Planted	240	240	240	240	240	240	240	240	240	189

Summary showing effect of mosaic on commercial varieties of cane in experiments at Pearl City and Waialua.

merara 1135, Lahaina, and Demerara 117. If the varieties be named in the order of their ability to grow and withstand the disease when infected, the following sequence is obtained from the experiment at Pearl City: Hawaii 109, Demerara 1135, Lahaina, Badila and Striped Tip. From the results of the experiment at Waialua they are placed in the following order: Demerara 117, Lahaina, Demerara 1135, Hawaii 109, and Yellow Caledonia. If the varieties be named in the order of their ability to recover from the disease, the following sequence is obtained from the results of the experiment at Pearl City; Demerara 1135, Striped Tip, Badila, Hawaii 109, and Lahaina. From the experiment at Waialua a somewhat different sequence results. It is as follows: Yellow Caledonia, Demerara 1135, Hawaii 109, Lahaina, and Demerara 117.

TABLE XII

Sample From	Brix	Polarization	Purity	Quality Ratio
Healthy D1135	20.55	18.28	88.96	7.26
Diseased D1135	20.35	18.08	88.85	7.34
Healthy Lahaina	21.75	19.93	91.63	6.55
Diseased Lahaina	20.25	18.25	90.12	7.25
Healthy Str. Tip	20.75	18.19	87.66	7.39
Diseased Str. Tip	18.00	15.20	84.44	9.08
Healthy H 109	21.05	18.12	86.08	7.53
Diseased H 109	21.05	18.14	86.17	7.53
Healthy Badila	22.05	20.44	92.70	6.32
Diseased Badila	21.25	19.55	92.00	6.64

Effect of mosaic on quality of juices. Experiment at Pearl City.

From these results and from the results of the two similar experiments at Puunene and Honokaa as well as from numerous field observations, the following conclusions regarding the behavior of different varieties toward mosaic seem justified. Striped Tip and Yellow Tip are very susceptible to infection and suffer severely when diseased, but show a rather high degree of recovery. The varieties Yellow Caledonia and Badila are very resistant to infection but suffer severely when diseased. They show a slight tendency to recover. The varieties Lahaina and Demerara 117 are very susceptible to infection but are not so severely injured as Striped Tip, Yellow Caledonia and Badila. Lahaina shows little ability to recover. No case of recovery has been observed for Demerara 117. The variety Hawaii 109 is moderately susceptible to infection, does not suffer severely when diseased, and shows considerable ability to recover. The variety Demerara 1135 is very resistant to infection, is not severely injured when diseased, and shows remarkable ability to recover.

The deleterious action of mosaic is most conspicuous in low yields of cane, but there is another important way in which sugar production is affected. In general diseased cane gives poorer juices than healthy cane, but in this respect also, the different varieties show marked differences. A test was made of the juices from healthy and diseased cane of the varieties grown in the experiments at Pearl City and at Puunene.

At the time these experiments were harvested, small samples were selected by taking one or more canes from each healthy and each diseased hill in four or more different rows of each variety. The writer is indebted to Mr. H. A. Cook, of the Experiment Station of the Hawaiian Sugar Planters' Association, for testing the samples from Pearl City; and to Mr. J. H. Pratt, of the Hawaiian Commercial and Sugar Company for testing the samples from Puunene. The results obtained are given in Tables XII and XIII.

TABLE XIII

Sample From	Brix	Polarization	Purity	Quality Ratio
Healthy D1135	19.99	17.83	89.2	7.44
Diseased D1135	19.29	16.10	83.5	8.65
Healthy Lahaina	22.17	20.55	92.7	6.29
Diseased Lahaina	20.14	17.30	85.9	7.88
Healthy Yel. Tip	18.89	16.21	85.8	8.42
Diseased Yel. Tip	18.04	14.39	79.8	10.05
Healthy H109	20.43	18.42	90.2	7.15
Diseased H109	19.88	17.57	88.4	7.60
Healthy Yel. Cal.	21.47	18.76	87.4	7.17
Diseased Yel. Cal.	19.79	15.61	78.9	9.35
Healthy D117	21.03	18.74	89.1	7.08
Diseased D117	19.76	16.94	85.7	8.06

The effect of mosaic on the quality of the juices in the experiment at Puunene.

The above tables show that in both experiments the disease had less effect on the juices of the variety Hawaii 109 than on those of any of the other varieties tested. The juices of Striped Tip, Yellow Tip and Yellow Caledonia were seriously affected; those of Badila, Demerara 1135, Demerara 117 and Lahaina were also considerably affected.

The total yield from all healthy seed of all varieties in the four experiments was 122,626 pounds, while the total yield from the same quantity of diseased seed of the same varieties was only 53,667 pounds. The stools from diseased seed yielded only 43.7 per cent, as much cane as those from healthy seed. From this data, it is evident that, for the average variety, diseased plants yield less than

one-half as much cane as healthy ones. In addition to cutting down the yield of cane, mosaic lowers the quality of the juices and, in this way, causes still further losses.

The experiments here described show that when infected, all of the varieties tested are more or less seriously injured by mosaic. Under favorable conditions for spread, it may cause considerable loss even in our most resistant varieties. On the other hand, under average plantation conditions in Hawaii there seems to be little danger of loss from mosaic where the variety Demerara 1135 is grown. It can hardly be expected to become a problem where such resistant varieties as Yellow Caledonia and Badila are grown. Moderate losses may be experienced in plantings of Hawaii 109 unless measures are taken to keep the disease under control. Serious losses are likely to occur wherever the varieties Striped Tip, Yellow Tip, Lahaina or Demerara 117 are planted.

According to the "Yellow Stripe Disease Survey" of 1920[3], there were in the 1920 and 1921 crops areas of diseased cane equal to approximately 115 acres on the Island of Kauai, 443 acres on the Island of Oahu, 953 acres on the Island of Hawaii, and 2,127 acres on the Island of Maui, or 3,638 acres on the four Islands. These figures were obtained by taking the different percentages of diseased cane reported for large areas and determining the number of acres this cane would actually occupy.

If it be assumed that the diseased cane in these crops yielded only one-half as much sugar as healthy cane would have yielded, then the number of acres of diseased cane on each island multiplied by one-half the average yield of sugar per acre during the two years gives a rough approximation of the losses caused by mosaic. The losses estimated in this way for the two crops harvested in 1920 and 1921 are as follows: for the Island of Kauai, 565 tons of sugar; for the island of Oahu, 2,483 tons of sugar; for the Island of Hawaii, 3,298 tons of sugar; and for the Island of Maui, 11,724 tons of sugar. The loss on the four islands amounted to 18,071 tons, or an average yearly loss of a little over 9,000 tons. While no survey has been made to determine the amount of mosaic in the crops now growing, it is believed that the situation is much better than in 1920. This improvement is largely due to a decrease in the areas in Lahaina, Demerara 117, Striped Tip and Yellow Tip, and to increased planting of the more resistant varieties Demerara 1135 and Hawaii 109.

Control

The foregoing results and observations suggest the following measures for the control of mosaic of sugar cane in Hawaii:

1. Wherever possible, grow varieties that resist the disease. Some of these are: Demerara 1135, Yellow Caledonia, Badila and Hawaii 109.

2. Plant healthy seed and keep fields as free as possible from the wild grasses on which the corn aphid breeds. Do not grow corn or any of the forage crops that are known to harbor the corn aphid in the vicinity of cane fields. Grasses subject to mosaic are especially dangerous.

3. Plow up badly diseased fields and replant with healthy seed of resistant varieties. Where only a small amount of mosaic is present, "rogue out" the diseased stools.

4. Try to obtain new varieties that resist the disease.

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EXPLANATION OF PLATE 24.

Fiji Disease. All figures × 1000.

Figure 1—A small intracellular body such as is common in young galls.

Figure 2—A small body with two short appendages.

Figure 3—A body containing numerous deep staining granules and having one short appendage.

Figure 4—A body with deep staining granules and a wavy hyaline appendage.

Figure 5—A body showing a small vacuole, deep staining granules and two appendages.

Figure 6—A typical body with two blunt appendages, the larger one having a wavy outline. This body also contains deep staining granules.

Figure 7—A body having a large central vacuole and two appendages, one of which is irregular in outline.

Figure 8—A common form of the Fiji disease body. The appendage is stained rather deeply and is not as sharply differentiated from the main part of the body as in most cases.

Figure 9—Another form of the body common in young galls.

Figure 10—An elongated body with one end larger than the other and with a short appendage at each end. This is a very common form.

Figure 11—A body showing two short, blunt, hyaline appendages.

Figure 12—A small elongated body having one rather long hyaline appendage.

Figure 13—A large oval-shaped body having one long hyaline appendage of wavy outline and with an enlargement at the tip.

Figure 14—A large irregularly-shaped body having several appendages, none of which is hyaline.

Figure 15—A body from an old gall. This body contains a central organ that resembles a nucleus and has three thin wavy appendages.

Figure 16—Another body from an old gall. The nuclear-like structures are surrounded by a thick membrane.

Figure 17—A body from a very old gall. The contents of the body have broken up into five distinct parts.

Figure 18—A body which is typical for the later stages in the development of young galls. The body still has a reticulate structure, but does not stain so deeply as do the bodies in younger galls.

Figure 19—A body from a very old gall. The slit in one end of the body and the granular structure is typical for the bodies in old galls.

Figure 20—Another typical body from an old gall. The inner granular parts are surrounded by a rather hyaline outer covering. The larger end shows a short slit.

EXPLANATION OF PLATE 24.—Continued.

Fiji Disease. All figures × 1000.

Figure 21—Two infected cells from a young gall, illustrating the variation in the size of bodies in adjoining cells. The cell to the right contains two small bodies, while the one to the left contains a very large body.

Figure 22—Three infected cells from a rather old gall. The central organs in these bodies resemble nuclei.

Figure 23—A body showing vacuolar structure. This is not a common form, but is occasionally seen in the older galls.

Figure 24—An infected cell undergoing mitotic nuclear division. A foreign body is shown at either end of the cell. The division of such a cell will give two infected daughter cells such as are shown in figure 25.

Figure 25—Two infected cells which have no doubt arisen through the division of a cell that contained two foreign bodies.

Figure 26—Mitotic nuclear division in an infected cell. This cell contains two foreign bodies of unequal size. Both are at the same end of the cell. Cell division in this case will probably give rise to one diseased and one healthy cell.

Figure 27—A cell containing a foreign body at each end. Many such cells are found in some young galls.

Figure 28—An infected cell with a much elongated foreign body near the host nucleus. The body seems to be in process of division.

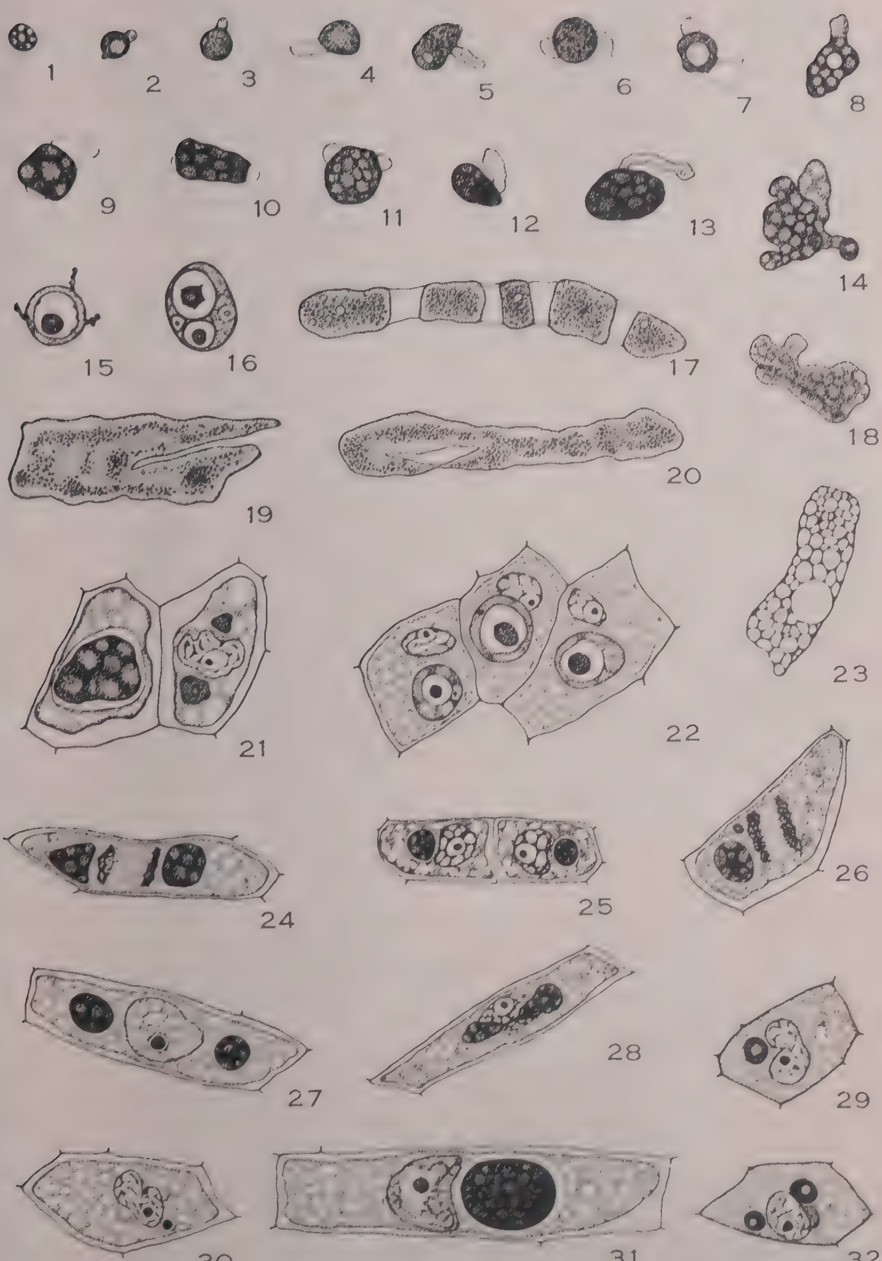
Figure 29—An infected cell from the edge of a young gall. The lobed appearance of the host nucleus is typical.

Figure 30—Another infected cell from the edge of a very young gall, showing the lobed condition of the host cell nucleus.

Figure 31—A typical cell from a rapidly growing gall. The host cell nucleus is somewhat crescent-shaped. The body occupies a vacuole in the host cell cytoplasm.

Figure 32—A cell from the inner portion of a very young gall. This cell contains three small foreign bodies. The host cell nucleus is not lobed.

PLATE 24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EXPLANATION OF PLATE 25.

Fiji Disease. All figures × 100.

Figure A—A longitudinal section through a young leaf near the terminal bud showing an early stage in the infection of a bundle. The two small, elongated, deeply stained areas located at either end of the picture are colonies of infected cells.

Figure B—A longitudinal section of a young leaf near the terminal bud showing a small colony of infected cells on the phloem side of the bundle.

Figure C—A longitudinal section of a young leaf near the growing point showing two small colonies of infected cells in the phloem of a young bundle.

Figure D—An oblique section through a bundle in a young leaf. A small colony of infected cells is shown in the phloem of the bundle.

Figure E—A longitudinal section through a young leaf showing a colony of infected cells. The infected cells are somewhat larger than the cells in the corresponding adjoining tissues. Spherical and elongated intracellular bodies are clearly shown in this picture.

PLATE 25

EXPLANATION OF PLATE 26.

Fiji Disease. All figures × 100.

Figure A—A cross section of a portion of a young leaf taken at a point a short distance above the terminal bud. Both bundles shown in this section are infected with the foreign bodies. The colony of infected cells in the bundle to the right are in the upper right hand corner of the bundle section. The infected cells in the bundle on the left occupy a more central position.

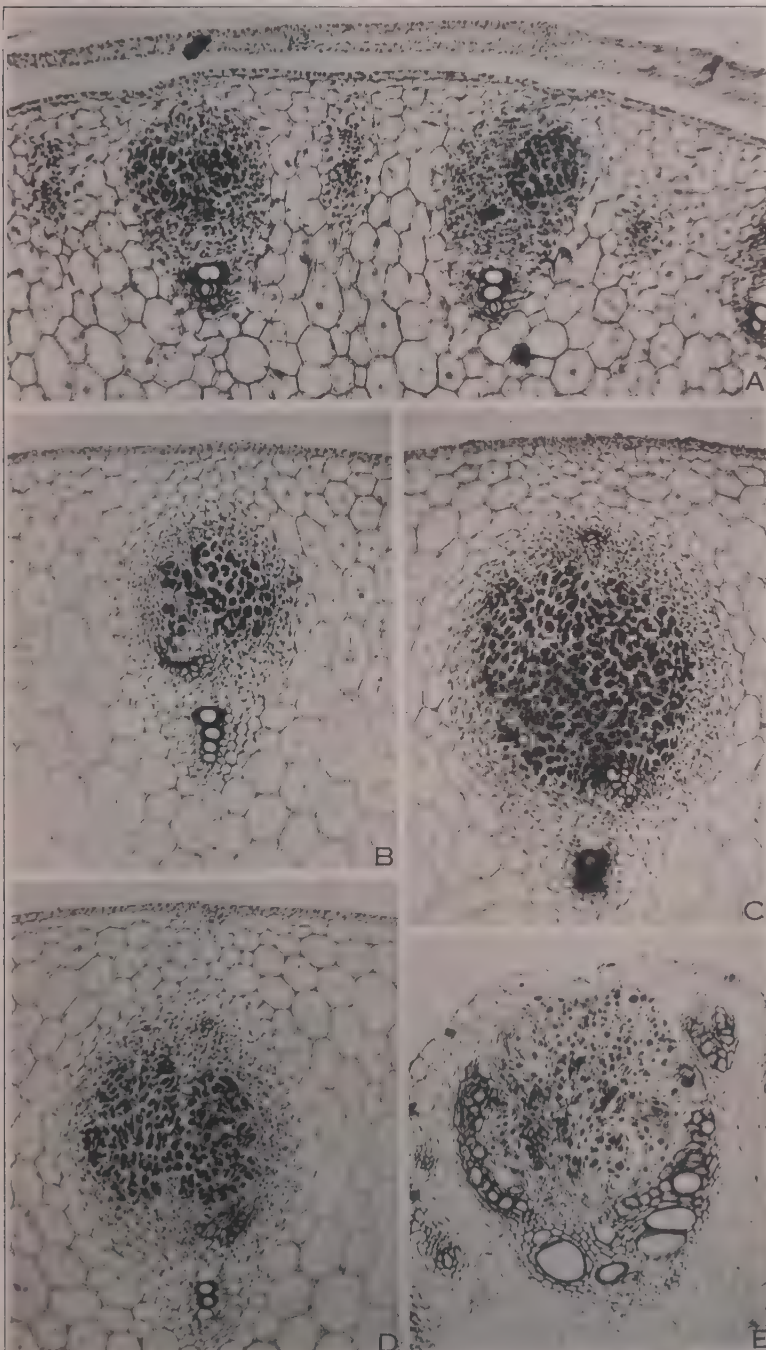
Figure B—A cross section of a portion of a young leaf showing the location of the infected cells.

Figure C—A cross section of a portion of a young leaf taken a short distance above the terminal bud. The infected cells in this bundle are making rapid growth.

Figure D—A cross section of a portion of a young leaf taken from the spindle of an infected plant. This section shows a stage in gall formation that is intermediate between the stages shown in Figures B and C. Figures A, B, C and D show successive stages in gall formation.

Figure E—A cross section through a portion of leaf sheath, showing the formation of sclerotic tissue around the infected tissue. This gall is much older than those shown in the other figures of the Plate.

PLATE 26



EXPLANATION OF PLATE 27.

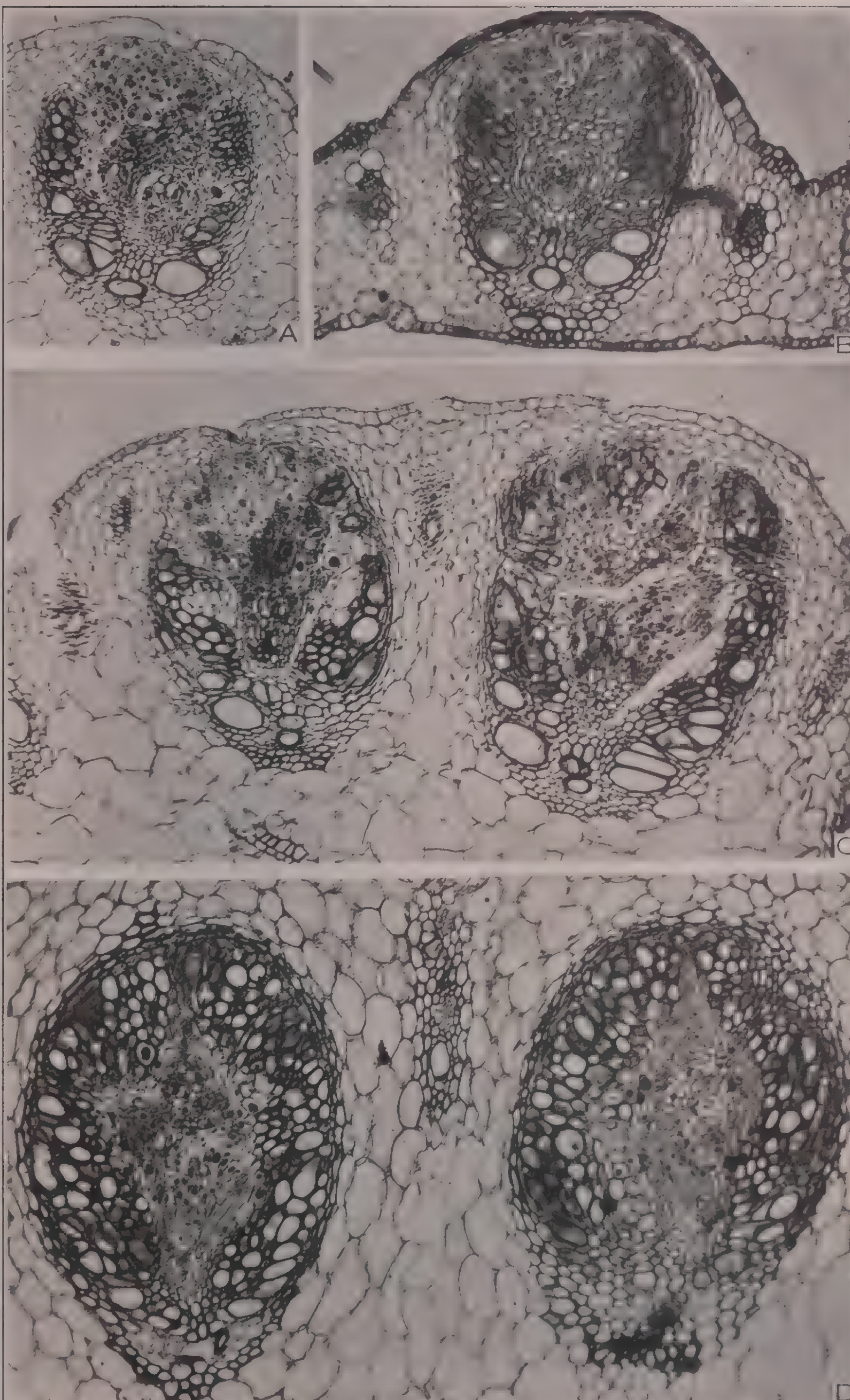
Fiji Disease. All figures $\times$ 100.

Figure A—A cross section of a portion of a leaf sheath showing the relation of the sclerotic tissues to the infected cells.

Figure B—A cross section through a portion of a diseased leaf, showing the development of sclerotic tissues around the infected cells. The gall is produced through abnormal growth in the tissues of the bundle.

Figure C—A cross section through a portion of a diseased leaf sheath showing the two infected bundles.

Figure D—A cross section through a portion of a diseased leaf sheath. In the galls shown here, the sclerotic tissues completely surround the infected cells.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EXPLANATION OF PLATE 28.

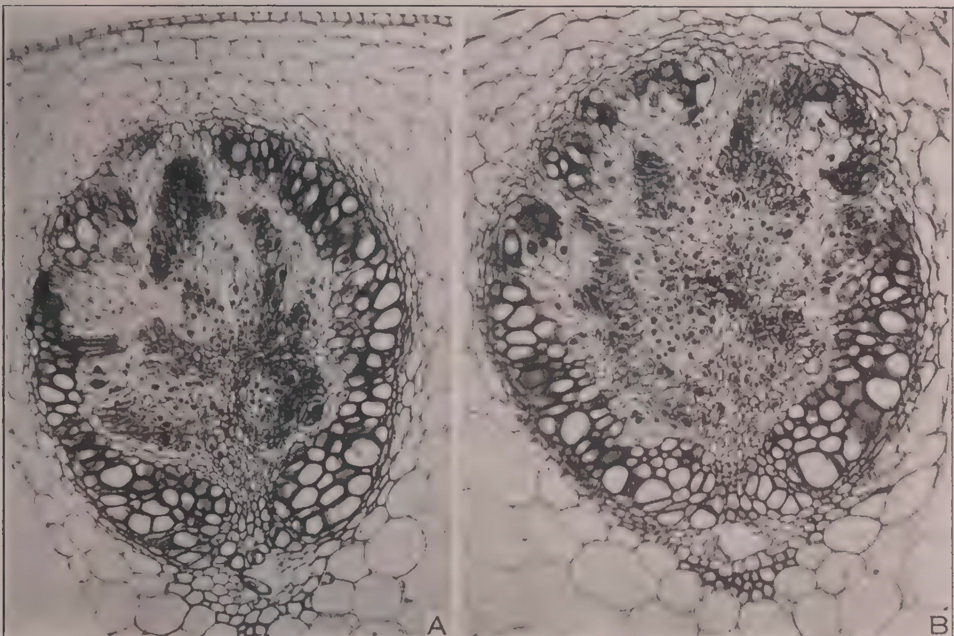
Fiji Disease. All figures × 100.

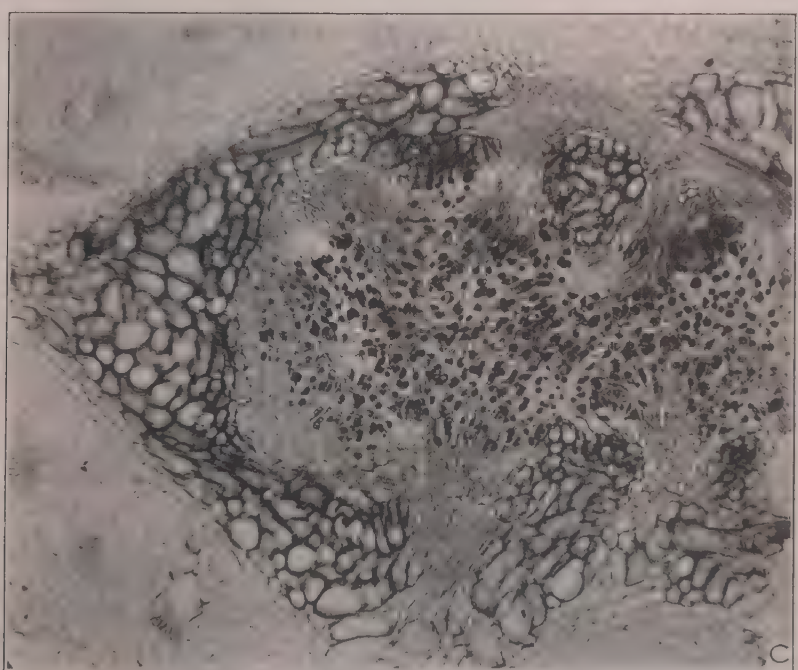
Figure A—A cross section through a portion of a diseased leaf sheath showing the relation between the infected and the sclerotic tissues.

Figure B—A cross section through a portion of a diseased leaf sheath, showing an old gall. The infected tissues are surrounded by a more or less broken sclerotic sheath.

Figure C—A longitudinal section through a portion of diseased stalk tissue. One end of an old gall is shown in this picture. The infected tissues are surrounded by a layer of thin-walled uninfected cells. Both of these tissues are enclosed in a somewhat broken sheath of sclerotic tissue.

PLATE 28





EXPLANATION OF PLATE 29.

The Intracellular Bodies of Hippeastrum Mosaic.

Figure A—A cross section through the upper portion of a diseased leaf. Three of the cells just beneath the epidermis contain amoeboid bodies. In each case the bodies are closely associated with the host cell nuclei. × 200.

Figure B—A cell containing a rather large irregularly shaped body which has a dense structure and is not closely associated with the nucleus. × 400.

Figure C—A cell containing a typical body in close contact with a crescent-shaped nucleus. × 400.

Figure D—A cell containing a body located at some distance from the nucleus. × 400.

Figure E—A typical body in close contact with its host cell nucleus. This body contains a large central vacuole. × 1000.

Figure F—A body connected with its host cell nucleus by means of a thin, veil-like appendage. × 1000.

Figure G—A large body containing a large vacuole and showing typical structure. This body is attached to the blunt end of its host nucleus. × 1000.

Figure H—A cell containing an elongated body suspended from the nucleus to the opposite cell wall. × 400.

Figure I—A body in a typical position on its host cell nucleus. × 400.

Figure J—A somewhat irregularly shaped body containing a large central vacuole. It is in close contact with its host cell nucleus. × 400.

Figure K—An elongated body closely applied to its host cell nucleus. × 1000.

Figure L—A small body such as is commonly found in the mature diseased cells of Tobacco plants suffering from mosaic. The body contains a central vacuole and is closely applied to its host cell nucleus. × 1000.

Figure M—A very small body located on its host cell nucleus. The chloroplast close by indicates the size of the body. × 1000.

Figure N—A large vacuolate body closely applied to its distorted host cell nucleus. × 1000.

Figure O—A small body in close contact with its elongated crescent-shaped host nucleus. × 400.

Figure P—A body containing several small vacuoles and located on its host cell nucleus. × 400.

Figure Q—A body containing a large central vacuole. This body is attached to the wall of its host cell, close to, but not in contact with, the cell nucleus. × 1000.

Figure R—An irregularly shaped body such as is commonly associated with sugar cane mosaic. This body is more irregular in shape than are those associated with corn, Hippeastrum or tobacco mosaic. × 1000.

Figure S—A parenchymatous cell from a mosaic tobacco leaf. A small foreign body is located near the nucleus. × 400.

PLATE 29

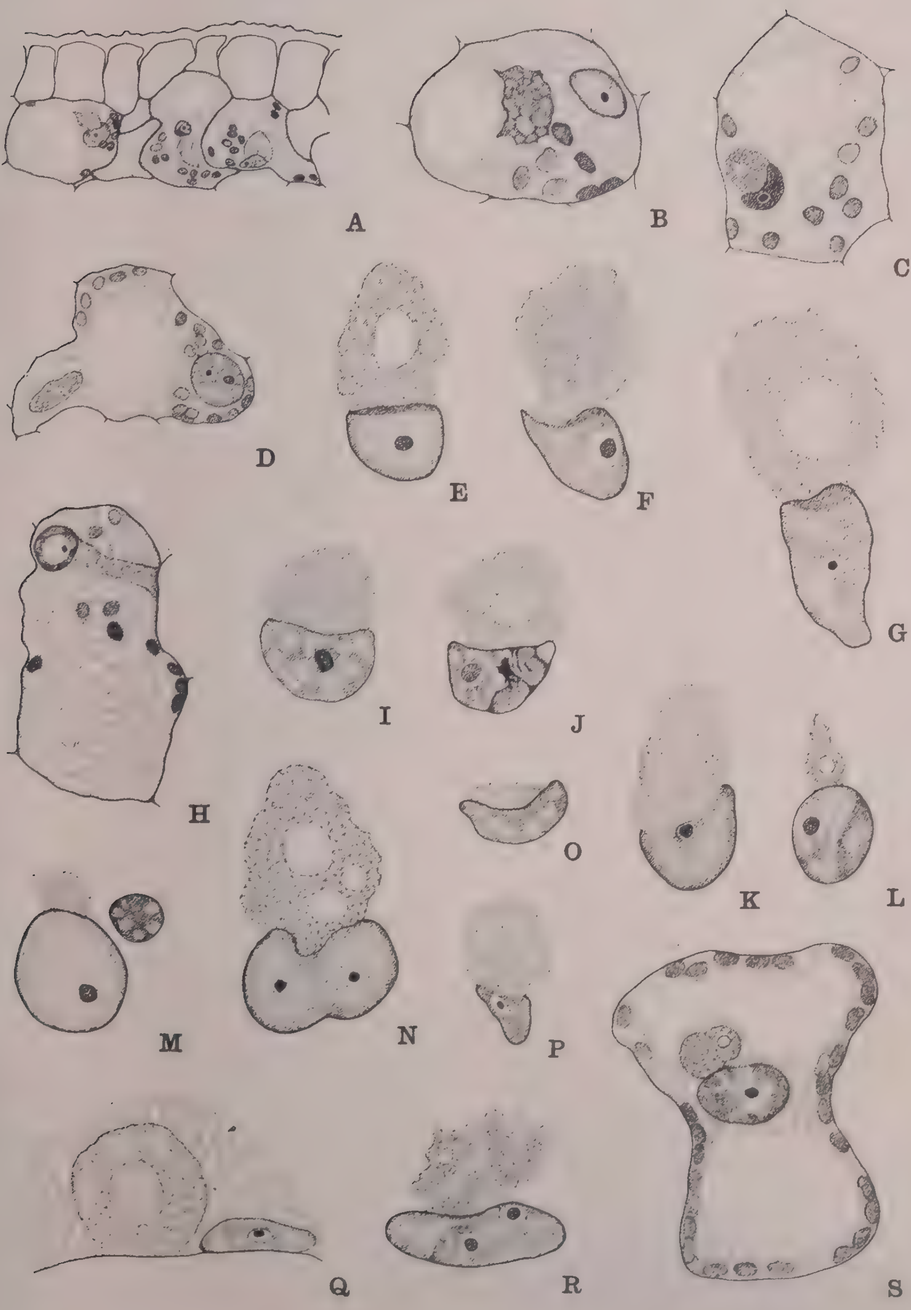


Figure 2—A portion of a mature leaf of the variety Striped Tip. The chlorotic areas consist of long stripes.

Figure 3—A portion of a mature leaf of the variety Striped Tip. The pattern shown by the chlorotic areas is the result of the fusion of many small spots.

Figure 4—A portion of an old leaf of the variety Striped Tip. Some of the chlorotic areas contain white or very light yellowish colored spots.

Figure 6—A portion of a young leaf of the variety Lahaina. The chlorotic spots are much smaller than those on young leaves of Striped Tip.

Figure 7—A portion of a mature leaf of the variety Hawaii 296. The pattern is typical for this variety.

Figure 8—A portion of an old leaf of the variety Hawaii 296. The spots have grown to such an extent that almost all of the tissue is chlorotic.